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THE UNIVERSITY OF ALBERTA

Spatial Orientation: Age and Head Injury Effects

by

Jocelyn B. Aubrey

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

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SPRING, 1988

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Abstract

In order to assess the effect of diffuse cerebral changes on spatial orientation abilities, the map-following performance of mildly head injured young (mean age = 29.6 yrs.) and healthy, non-head injured elderly persons (mean age = 67.8 yrs.) was compared to that of young, non-head injured people (mean age = 35.3 yrs). There were an equal number of males and females in each group. Subjects were given maps with nine location dots in a 3 x 3 matrix that corresponded to nine red discs on the floor of the experimental room. Six maps were presented with paths increasing by one segment in length with each subsequent map. In one condition (Variant), participants were asked to walk the path outlined on each map while not turning the map and thus varying the orientation of the map to the room. In a second condition (Invariant), participants turned the maps while following the routes, keeping them aligned with the north wall of the room. In a third and fourth condition, verbal instructions were given for completing one of the maps. These instructions were given as external compass coordinates or as right-left body coordinates.

In Experiment 1 comparing elderly persons to young people, elderly persons made more errors and took more time to make direction decisions than younger people. Similarly, females, especially elderly females, made more errors and took more time than males to make direction decisions. For both elderly and

young people, decision times were influenced by the direction and angle of each turn and, in the Variant condition, by the angular disparity between the map and the room. Elderly persons, especially females, were influenced more by these factors than young people. Elderly persons were more likely to rate their senses-of-direction on a questionnaire as poor compared to young people and this correlated with slower performance on the map-following tasks.

In Experiment 2, head injured persons did not make more errors than non-head injured controls although they took longer to make direction decisions. As in the first experiment, the performance of all participants in the Variant condition was influenced by the angular disparity of the maps to the room; the greater the misalignment of the map from north, the longer the decision time. Head injured persons rated their senses-of-direction and other wayfinding abilities as poorer than non-head injured subjects, but there were no significant correlations between these ratings and performance measures.

The difficulties in spatial orientation experienced by elderly persons whose diffuse cerebral changes have occurred gradually, are not unlike the difficulties experienced by victims of minor head injury. These changes in orientation abilities may reflect slower information processing and deficits in working memory capacity.

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Introduction

Research on human spatial orientation spans several domains and subject populations that include normal, healthy persons of all ages as well as individuals suffering focal brain damage. In contrast, there has been little research on the changes in orientation abilities that take place as a result of aging or mild trauma of the brain. The study reported here was undertaken to investigate differences in performance between young and elderly persons, and head injured and non-head injured persons on a map-following task of spatial orientation. This introduction will, first, integrate information about changes in spatial orientation that have been reported in several different areas of research and second, present an experimental methodology designed to investigate spatial orientation while minimizing memory demands.

Types of Orientation

Neurological research on war victims injured by missiles to the head has demonstrated a dissociation between two types of orientation. In one type, intrapersonal orientation, the body is the referent coordinate. The second type, extrapersonal orientation, occurs when objects external to the body serve as referents. Subjects with frontal wounds showed deficits on tasks of intrapersonal orientation while parietal damage resulted in greater difficulty with extrapersonal orientation (Butters, Soeldner &

Fedio, 1972; Semmes, Weinstein, Ghent & Teuber, 1955, 1963; Weinstein, Semmes, Ghent & Teuber, 1956).

Intra- and extrapersonal spatial orientation have been differentiated in the following way: "When voluntary movements are executed in intrapersonal space, the task is that of moving a part of the body relative to other body parts...Movements in extrapersonal space, in contrast, are movements executed in a three-dimensional coordinate system fixed by points in the environment. Now the task is to move part of the body (or whole body) toward a target in the extrapersonal coordinate system...the type of information the brain requires to organize a movement in extrapersonal space is different from that required for movements in intrapersonal space, and it consists both of the spatial relations in extrapersonal space and the transformation rules between the two reference systems." (Roland, Skinhoj, Lassen & Larsen, 1980, pg. 138).

Although general spatial abilities usually have been ascribed to right hemisphere activity (Benton, 1979), some researchers have argued that extrapersonal orientation requires bilateral input (Butters & Barton, 1970; Semmes et al., 1963). Others have claimed it is specifically a right parietal effect (De Renzi, Faglioni & Villa, 1977; Newcombe & Russell, 1969; Ruff, Hersh & Pribram, 1981). De Renzi, Faglioni and Scotti (1971) have pointed out that bilateral effects were usually found with complex orientation tasks such as the Locomotor Maze (Ratcliff &

Newcombe, 1973; Semmes et al., 1955, 1963) which probably required the integration functions of the left hemisphere. When the participant was required to reproduce the orientation of a rod in space, a simple test of 'pure' spatial functioning, only patients with right parietal lesions exhibited impaired performance (De Renzi et al., 1971).

The issue of hemispheric localization has also been investigated in studies using non brain-damaged participants. Research using regional cerebral blood flow measures (rCBF) demonstrated the cerebral dissociation between intra- and extrapersonal movements but found bilateral involvement for extrapersonal tasks (Roland, Larsen, Lassen & Skinhoj, 1980; Roland, Skinhoj, Lassen & Larsen, 1980). In contrast, measurement of evoked potentials (EP) indicated right parietal activation for a task where, using either hand, participants determined the orientation of a rod (Desmedt, 1977). Once again, the complexity of the tasks used may well explain the involvement or non-involvement of the left hemisphere. In the Roland et al. (1980) research, the maze task required the participant to move a finger one or more grid sections in different specified directions as fast as possible and probably required relatively complex processing. No doubt, De Renzi (1978) would argue that due to the increased complexity of the maze task, the integration capabilities of the left hemisphere were involved.

Movements in extrapersonal space require intrapersonal as well as extrapersonal mechanisms. RCBF research has shown that with the addition of two areas in the posterior parietal lobes, cerebral areas activated during extrapersonal movements were the same as those activated during intrapersonal movements (Roland et al., 1980).

The above discussion indicates that orientation in space requires the integrity of more than just one region or hemisphere of the brain. The rCBF and EP methodologies are valuable for investigating neural activation using very simple laboratory tasks but they have not yet been adapted for use during complex procedures involving larger movements in space. It is necessary, therefore, to use behavioural measures to further investigate the spatial orientation abilities of normal individuals and those with diffuse rather than focal brain damage.

The methods used in this research were designed to take a closer look at the processes involved in spatial orientation with reference to life-span changes and the effects of mild head trauma. The neurological changes that occur with normal aging are generally diffuse (Katzman & Terry, 1983) as are those that occur with closed head injury (Levin, Benton & Grossman, 1982). As the evidence presented above indicates, successful orientation in space depends on an intact cerebrum for optimum efficiency. One might expect, therefore, that advancing age or head injury

would impair spatial orientation.

Spatial Orientation and Aging

None of the research on age related changes in spatial abilities has focused specifically on intra- or extrapersonal orientation. However, there are three areas of spatial research that can be reinterpreted in these terms. These are perspective taking, mental rotation, and environmental cognition.

Perspective-taking. Successful mental imaging of differing perspectives is an essential component of orienting in space. This usually requires the mirror-imaging or mental alignment of objects in space to our own left-right body coordinates. Such mental imaging, with one's own body as the major referent, could be classed as primarily intrapersonal in nature.

The majority of research has been conducted within the paradigm of the perspective-taking task of Piaget (Piaget & Inhelder, 1967). Egocentrism (the inability to take the visual perspective of others) has been identified as an early stage in the development of childrens' spatial orientation abilities. A typical perspective-taking experiment involves presentation of a display (often three-dimensional) to a participant seated at a 45° angle from the experimenter. The participant is asked to either reproduce the display from the experimenter's perspective or to indicate the correct item from a series of alternatives displayed by the experimenter.

In studies of human aging, the usual finding is that young adults perform with greater speed and accuracy than older adults (Herman & Coyne, 1980; Rubin, 1974; Rubin, Attewell, Tierney & Tumolo, 1973). The notable result from the research on aging and perspective-taking, is the lack of evidence for systematic egocentric responding (Kirasic & Allen, 1985). If egocentric responding was consistently apparent, researchers would conclude that such a 'child-like' mode of responding indicated an age-related dissolution of an ability acquired at an earlier developmental stage. The evidence garnered so far suggests that the difficulty older participants have with perspective-taking tasks is not due to cognitive dissolution (Kirasic & Allen, 1985). Herman & Coyne (1980) suggest that task demands in perspective-taking experiments are greater for elderly people due to the slowing of cognitive processing which strains the capacity of working memory.

Mental Rotation. The mental images we have of objects in our environment occupy a representational space in which cognitive manipulations such as mental rotations and spatial transformation can take place (Corballis, 1982). The majority of research on mental rotation has been conducted within the paradigm of Shepard and his associates (Cooper & Shepard, 1973a, 1973b; Shepard & Metzler, 1967). The region of representational space investigated in these studies contained only the patterns to be rotated. However, representational

space can become a "potential environment...in which one can imagine oneself moving about. With respect to mental rotation, one can then contrast mental rotation of the environment with mental rotation of the self" (Corballis, 1982, pg. 78). This mental imaging of one's environment, if it involves the mental rotation of the body as it seems to do in perspective-taking tasks, could be considered intrapersonal in nature. When one imagines the rotation of the environment or an object in the environment, as in the rotation of a pattern or letter in a typical Shepard task, one may be using extrapersonal spatial mechanisms.

The traditional Shepard & Metzler (1971) task was designed to measure response time to make decisions requiring mental rotation of a shape. Two experimental procedures have been used. One requires the participant to match pairs of patterns or objects presented in different orientations. The second procedure utilizes the presentation of a familiar pattern with the participant required to judge if the pattern is normal or backward (ie. mirror reversed). Research indicates that the time necessary to make these judgements is a linear function of the angular difference between the pattern and its normal upright position (Cooper & Shepard, 1973a, 1973b). The same relationship between response latency and angular disparity is evidenced in research with aging participants, but elderly persons are considerably slower than young (Berg, Hertzog & Hunt, 1982;

— Cerella, Poon & Fozard, 1981; Gaylord & Marsh, 1975). In addition, all three studies reported age x angle interactions such that the slope of the mental rotation function of elderly persons was steeper than that of young people.

Macrosatial/Environmental Cognition. Macrosatial, or environmental cognition is "the study of the acquisition and utilization of knowledge of the spatial attributes of large-scale environments...an area the structure of which cannot be perceived from a single standpoint within that area" (Kirasic & Allen, 1985, pg. 204). Research in real-world settings has stressed the analysis of the cognitive maps developed by participants and emphasized the salience of landmarks, paths and boundaries (Evans, 1980). The emphasis in this area of research is on the use of external cues as referents for orientation, and thus participants rely extensively on extrapersonal spatial mechanisms.

In large-scale environments the ability of elderly persons to recognize landmarks or spatial perspectives is impaired compared to younger individuals (Ohta, 1983; Ohta, Walsh & Krauss, 1981; Weber, Brown & Weldon, 1978). Since macrosatial cognition "involves the storage, retrieval, and integration of spatial information over time" (Walsh, Krauss & Regnier, 1981, pg. 352), it is quite likely that some of the difficulty elderly individuals have with tests in large-scale environments is due to the memory deficits associated with aging (Kausler, 1982).

Research conducted in familiar environments such as the participant's own neighborhood (Walsh et al., 1981) or supermarket (Kirasic, 1981 cited in Kirasic & Allen, 1985) indicated that, for elderly persons, familiarity with the environment predicted optimum use of, and efficiency within, that environment.

A research perspective that involves locomotion in larger spaces, but is laboratory rather than real-world based, has been used in a series of studies conducted in Sweden (Book & Garling, 1980a, 1980b, 1981a, 1981b). The emphasis is on locomotion and orientation in unfamiliar spaces as opposed to the familiar environments characterizing most of the studies on environmental cognition. Although varied somewhat for different studies in the series, the basic procedure involved having participants estimate distance and direction to lighted targets in a darkened experimental room. As a result of these studies, the researchers have concluded that maintenance of orientation during locomotion in unfamiliar environments is achieved by recurrent encoding, coordination, and decoding of information about direction and locomotion distance (Book & Garling, 1980a). This involves central processing capacity which can be interfered with by the imposition of a concurrent task (Book & Garling, 1980b). When delays were introduced into the procedure, the authors explained that "forgetting may account for the errors, but the main factor

was assumed to be accumulated errors in recurrent central processing of the sensory information received about locomotion distance and target location" (Book & Garling, 1981a, Pg. 995). Furthermore, different types of errors occurred with maintenance of orientation during body rotation than occurred with straight walking, suggesting that different mechanisms might be involved (Book & Garling, 1981b). Unfortunately, age differences have not been investigated by these researchers. Slower central processing has often been cited as the cause of deficits in the performance of elderly persons on many cognitive tasks (Birren, 1974). One would expect that older people might show performance deficits on the Book and Garling procedures.

Mild Head Trauma and Spatial Orientation

A remarkably minimal amount of research has been conducted on the cognitive performance of persons who have experienced a whiplash or direct head injury not involving coma or extensive loss of consciousness. This seems to be due to reluctance on the part of the research community to accept the existence of significant cognitive impairments in the absence of traditional physiological indices (eg. CT scans) of damage. Commonly, patient complaints of memory and concentration problems, disorientation and getting lost have been dismissed as neurotic (Lishman, 1973; Miller, 1961) or as malingering (Raskin, 1985). Brain scans of mildly head injured persons have not indicated

physiological damage. However, Oppenheimer (1968) documented the presence of microscopic changes in the cerebral white matter of such patients who died of causes not related to head injury. As well, research with monkeys has demonstrated that rotational impact (whiplash) injuries such as occur in many rear-end vehicle collisions, result in cerebral contusions (Adams, Graham & Gennarelli, 1982) and in some cases degeneration of the brainstem reticular formation (Jane et al., 1982).

The little research that has been conducted on spatial abilities has focused on an assessment of performance on psychometric tasks such as the performance tests of the WAIS and the Halstead-Reitan Trail-Making test with results indicating deficits by individuals having had mild head trauma (Dikman, Reitan & Temkin, 1983; O'Shaughnessy, Fowler & Reid, 1984). Although people with mild head injuries often complain of wayfinding difficulties (Barnat, 1986), there has been no research investigating the spatial orientation abilities of such individuals.

Sex Differences and Spatial Orientation

The bulk of research into sex differences and spatial ability indicates that males are generally superior at performing spatial tasks (Harris, 1981; McGee, 1979). These differences are apparent in tests of several kinds of spatial ability including mental rotation (Tapley & Bryden, 1977), right-left differentiation

(Harris & Gitterman, 1978), imagined route-following (Tapley & Bryden, 1977) and paper and pencil maze tasks, (Porteus, 1965).

Although the majority of studies investigating sex differences in spatial skill report male superiority, the finding is not unanimous (Harris, 1982). One study that is especially relevant to the proposed research is one undertaken by Teng & Lee (1982) with high school students who completed the Locomotor Maze test of extrapersonal orientation (Semmes et al., 1955). Teng & Lee reported a very small, but not significant, male advantage on this task but concluded that the large within-group variances and extensive overlap of the score distributions had much greater implications for an understanding of human spatial abilities than any sex differences that were to be found. It should be noted that the conclusions drawn by these researchers were based on one measure of performance, an overall score. As the results of the study to be presented indicate, finer measures might have yielded different results. Although sex-differences are commonplace on two-dimensional paper and pencil psychometric tasks, the evidence from studies assessing peoples' cognitive maps does not support male superiority in environmental cognition (Evans, 1980).

Studies of sex differences in relation to aging have been limited, although the few that have been reported tend to uphold the general finding of male superiority on psychometric tests of spatial ability (Nesselroade, Schaie & Baltes, 1972; Schaie &

Strother, 1968), mental rotation (Berg et al., 1982) and perspective-taking ability (Herman & Coyne, 1980). Cohen (1976) equated participants on perspective-taking ability and found that older men were more adept than were older women at making spatial decisions in reference to body orientation. At the same time, both sexes had difficulty on a spatial visualization task that required participants to imagine spatial displacement or movement in reference to an external object.

Many studies investigating the spatial orientation abilities of the elderly have simply not looked at sex as a factor in the research. One reason for this must certainly be due to the preponderance of women in the older age groups as well as their greater willingness to participate in research. Possible sex differences have not been taken into account in the limited number of studies investigating mild head injury.

Direction-Sense and Spatial Orientation

Research on self-reports of direction-sense have been reported from two different laboratories. Sex-differences are reported by one group, with males indicating less likelihood of right-left confusion than females (Harris & Gitterman, 1978; Thompson, Harris & Mann, 1980). Women also made significantly more errors than men on an objective test requiring the identification of right-left orientation of pictures of body parts projected on a screen (Harris & Gitterman, 1977 cited in

Harris, 1981). Self-ratings of direction-sense were correlated with performance, although unrelated to sex, on a maze learning task, a map drawing task, and a task assessing the direction location of familiar buildings (Kozlowski & Bryant, 1977). No attempts have been made to assess direction-sense among elderly persons or head trauma victims.

Rationale for the Current Research

The Locomotor Maze was the task used by Semmes et al. (1955) to assess the ability of brain-damaged men to orient in extrapersonal space. This is a map-following, laboratory test that requires the individual to maintain orientation despite repeated turns that result in shifts in body position. Participants are given maps with nine location dots in a 3 x 3 matrix corresponding to nine red discs on the floor of an experimental room. They are asked to walk the path outlined on each map. The need to maintain orientation in relation to objects in external space (i.e. the map and the location dots on the floor) requires the individual to use extrapersonal orientation abilities. The individual is not allowed to physically rotate the map, while traversing the route. Hence, the person must mentally rotate it to keep his or her body position correctly oriented. This requires intrapersonal spatial mechanisms. The Semmes et al. task is eminently suitable as a procedure to investigate the spatial orientation abilities of

normal, healthy individuals as well as brain-damaged persons. (A full description of the Locomotor Maze task is presented in the Methods section).

This particular task was chosen as a vehicle for assessing aging and minor head injury effects on spatial orientation because it places minimal memory demands on participants. This contrasts with most of the research cited above on macrospatial cognition. Those studies used tasks that assessed memory for landmarks or perspectives. Since the participant was able to see the whole stimulus environment at once, manipulations to the Locomotor Maze allowed assessments of spatial orientation independent of long-term memory demands.

The Locomotor Maze task consists of six maps (Ratcliff & Newcombe, 1973). Each successive map has an increasing number of turns. Earlier research (Aubrey, 1986) demonstrated that elderly persons made more errors on the more complex maps (those with the greater number of turns) and took more time to complete maps than was required by younger persons. The time measure in that study was a gross measure of total time to complete an entire route. By dividing the total time by the number of route segments and adjusting this for differences in walking time between the two age groups, a basic "per segment" time measure was calculated. Significant differences between the two groups were found on this time measure. However, the measure did not allow for the

differentiation between time to make decisions and time to walk the segments, nor did it allow the separation of decision times at varying locations along the route. In the current research, much finer time measures were taken. The amount of time the person remained at each location dot was recorded separately from the time taken to walk each segment. It is mostly while stopped at location dots that participants were updating orientation information in relation to the external coordinates of dots on the floor and map. As well, they were updating their ordinal position in relation to the North wall of the room and the North edge of the map. In fact, participants were instructed to complete their decision making for each segment of the route while remaining on the dot. Thus, the time stopped at each dot was presumed to represent the mental processing time required to make a direction decision. Completing the Locomotor Maze in this, its basic form, constituted the first experimental condition and provided a measure of orientation in external space. Participants needed to mentally rotate the maps in order to orient correctly while constantly changing their own body positions as they progressed through the various turns indicated on the map.

In a second condition, participants were required to physically rotate the maps, keeping them in a constant orientation with respect to the North wall of the room and

thereby eliminated the need for mental rotation. In effect, participants were now making simple right-left direction choices when stopped at each location dot. This changed the task to one that required a much greater reliance on intrapersonal orientation mechanisms.

It is quite probable that the need to remember on which dot one was standing at any one time while proceeding along the route may influence performance. Hence, a third and fourth condition were designed to assess spatial orientation on the maps that eliminated even these minimal short-term memory requirements. In those conditions, the experimenter gave verbal instructions to the participant regarding location moves. Directions were given as either north-south-east-west extrapersonal coordinates (condition three) or as right-left intrapersonal coordinates (condition four).

Method

Subjects

Participants in both experiments were assessed for visual acuity, using the Snellen Eye Chart. With the exception of six persons, all subjects had corrected bilateral vision of 20/25 or better. Four elderly participants had corrected bilateral vision of 20/50, one head injured person had 20/30 and one had 20/40 vision. The visual acuity of all participants was deemed adequate for the large map stimuli used in this study. Alcohol use was assessed through questions about amounts and kinds of alcohol consumed. Appendix A lists the questions and average consumption ratings for each group. Ten subjects reported consumption of alcohol that was far in excess of the average for their groups. For these subjects, the total scores for each version of the map-following task were compared to group means. Six of the ten scored below the mean in one condition, and one scored below the mean in the other condition. It was concluded that the influence of alcohol consumption was no more than chance. Consequently, the data for these subjects was included in all analyses.

Experiment 1

Sixty-four volunteers participating in the Lifespan Adult Memory Project (L.A.M.P.) in the Psychology Department of the University of Alberta were divided into two age groups; 29-41

yrs., and 59-77 yrs. An equal number of males and females were recruited for each group. The groups did not differ on years of education or WAIS Vocabulary scores. Subjects had no known history of head trauma within the previous five years.

Experiment 2

The participants were thirty-two volunteers in the L.A.M.P. study who had experienced either a direct blow to the head or a whiplash injury. Although some subjects had been involved in more than one accident, none had experienced more than two head injuries. The most recent head injury was characterized by a loss of consciousness (LOC) of less than one hour. Ages ranged from 22-39 years and there were an equal number of males and females. The young group from Experiment 1 served as the control group. It was not possible to have groups matched on age since the recruitment age of subjects to the L.A.M.P. study began at 30 while many of the trauma victims were younger. Due to a variety of physical symptoms, the overall health ratings of the injured persons were poorer than those of the other two groups. Tables 1 and 2 list demographic data for the three groups.

Table 1

Demographic Characteristics of Elderly, Young,
and Head Injured participants: Means and (SDs)

	n	Age in yrs.	Educ. in yrs.	Vocab. /80	Health ¹ Rating
Elderly Females	16	67.4 (3.7)	13.1 (2.2)	65.4 (8.5)	.69 (.6)
Elderly Males	16	68.2 (5.6)	14.3 (3.2)	61.7 (11.1)	.50 (.8)
Young Females	16	33.6 (3.5)	14.3 (2.4)	61.8 (10.1)	.75 (.6)
Young Males	16	36.9 (3.1)	15.8 (2.9)	63.9 (8.3)	.69 (.5)
Trauma Females	16	29.1* (5.6)	12.9 (1.5)	50.0* (13.4)	1.50* (.7)
Trauma Males	16	30.1* (5.9)	13.7* (1.7)	52.4* (13.6)	1.30* (.9)

¹ Health Ratings: 0-Excellent, 1-Good, 2-Fair, 3-Poor

* Means were significantly different from control, $p < .05$.

Table 2

Accident Data for Head Injured Subjects: Means and (SDs)

	n	No. of Accidents	Months since last accident	LOC last acc. (in min.)
Females	16	1.4 (.5)	25.9 (rng:4-51) (12.8)	2.39 (8.3)
Males	16	1.4 (.5)	15.9 (rng:9-55) (15.6)	12.4 (21.9)

Materials

Orientation and Direction-Sense

Prior to testing on the Locomotor Maze, a questionnaire was administered which assessed the respondent's perceived sense of direction and way-finding abilities (see Appendix B for questionnaire). Some of the items were derived from other questionnaires assessing sense-of direction (Koslowski & Bryant, 1977), right-left difficulty (Harris & Gitterman, 1978), wandering of demented patients (deLeon, Potegal, & Gurland, 1984), and environmental orientation (Garling, 1980).

This questionnaire was changed somewhat for the head injured subjects (Appendix C). For this group, the first set of questions related to pre-injury wayfinding abilities, and the second set related to post-injury assessments.

Locomotor Maze

In order to control the number of right and left turns and the angular differences between maps, six new test maps were designed to replace those used in previous research (Aubrey, 1986; Ratcliff & Newcombe, 1973). The number of turns on the test maps increased sequentially from 6 on Map 1 to 11 on Map 6. Within the constraints of a square matrix of nine dots it was virtually impossible to distribute turns such that there was an even number of right and left turns for each angle of turn. Over the final six test maps, there were 25 right and 26 left turns.

In combination with these were 12 45° turns, 17 90° turns, and 22 135° turns as illustrated in Figure 1. Because subjects had apparently needed test Map 1 of the earlier study (Aubrey, 1986) for further practice, three practice routes, rather than two, were designed for the present study.

Maps were drawn on 30 cm square white cardboard sheets with the paths drawn in heavy black ink. Starting points were indicated by a circle and the endings by an arrowhead. North was marked on each of the maps and participants were informed that the experimenter was standing in front of the North wall of the room. Nine dots, each 15 cm in diameter and cut from red mactac, were stuck to the floor in a bare experimental room and laid out in a three by three arrangement approximately 150 cm apart. In order to eliminate any external cues, the walls of the experimental room were covered by plain, untextured curtains. Instructions required the participant to walk directly forward -not backward or sideways. The maps were always given to the participants on the starting dot of each map while facing North. Participants were given feedback during the three practice trials and allowed to make corrections, but no knowledge of results were given on test trials. On test trials, if a participant discovered, after reaching a disk, that an error had been made, he or she was allowed to return to the previous disk and try again. If this happened more than twice on the same disk, the

trial was to be terminated and a new map begun. In actual fact, however, there were no subjects who retraced a segment more than twice.

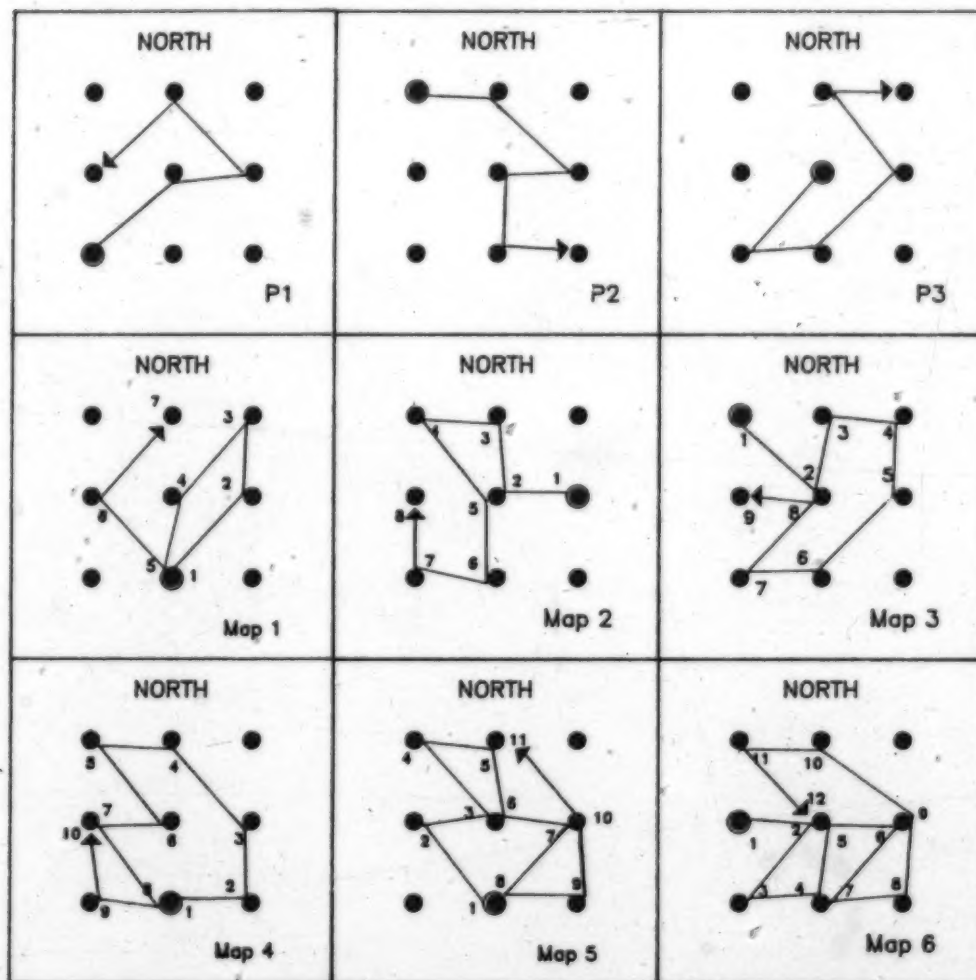


Figure 1. Practice and test maps of the Locomotor Maze task designed for this study. Starting dots are circled. On the six test maps, route dots are numbered in sequential order. Route dots were not numbered on the maps used by participants in this research.

Conditions

The Locomotor Maze task was presented to participants in four different instructional conditions. Instructions for these conditions are provided in Appendices D-G.

Room Variant Condition. In this condition, subjects were required to hold each map with the North side farthest from their bodies throughout the trial and instructed (Appendix D) not to turn the map in any way. Consequently, although the map was in a constant orientation relative to the individuals, its orientation to the room varied as they walked the route.

Room Invariant Condition. Instructions (Appendix E) and materials for this condition were the same as for the Variant condition with the exception that participants were required to turn the maps throughout the trial, keeping the North edge of the map in a constant orientation to the North wall of the room. Care was taken to be sure that the necessity of turning the maps was understood by the participants before testing began.

Verbal Conditions: External and Body Coordinates. In these conditions, participants were not given maps but were asked to follow verbal instructions for completing Map Six. In the External-Verbal condition, instructions (Appendix F) were given as compass coordinates. In the Body-Verbal condition the instructions (Appendix G) were given as right-left body turns of 45°, 90°, or 135°. The purpose of the two verbal conditions was

to determine if subjects could orient in intra- and extrapersonal space without the need to remember specific locations or relationships among dots. The route outlined on Map Six involved twelve location dots which was deemed adequate for the purpose and hence the verbal instructions corresponded to the route of this map.

Design

A repeated measures design was employed with all participants completing the four instructional conditions. The instructional differences between the Variant and the Invariant conditions could be very confusing if these two conditions were presented to a participant on the same testing day. For this reason, two test sessions were employed with these conditions presented on separate days. It was impossible to completely randomize the ordering of the maps within each condition. Earlier research (Aubrey, 1986) had indicated that differential decline in performance between young and elderly subjects became evident with Map 4. Therefore, two map orderings were devised, Maps 1-6 in sequential order, and Maps 4, 5, 6, 1, 2, 3. Sixteen orderings resulted when the two verbal conditions, two map-following conditions, and two map-orders were counterbalanced over the two testing sessions. Because there were 32 subjects per group, one male and one female in each group received each of the different task orders.

Procedure

The experimenter stood at the North end of the room in front of a lectern which held a Hewlett-Packard 41-C electronic calculator with stopwatch module for recording times, and score sheets on which the participants' routes were drawn. A video camera was installed on the ceiling in the Northwest corner of the room to record participants' performance. This procedure allowed the experimenter to recheck timing and accuracy of route drawings when necessary.

The time spent on each dot was recorded in order to give a measure of decision time. Timing for decision-making began the moment the participant stepped on a dot and ended as soon as he or she stepped off. For the first dot of each map, the experimenter lead the participant to the correct dot and made sure he or she was facing North. The participant had been given the stack of six maps, covered by a blank card, at the beginning of testing and asked not to turn to a new map until instructed to do so. Once at the correct location, the participant was instructed to turn up the next map. Timing began at that moment. In the verbal conditions, timing began immediately after the experimenter finished the instruction and ended as soon as the participant stepped off the dot. Once the participant made a direction choice, he or she turned, stepped off the dot and proceeded to the next location. Theoretically, it may seem

possible to record turning time separately, however pilot work indicated that participants behaved differently. Some would stand on the dot, make up their minds, and then turn and immediately walk to the next location. Others would turn slowly on the dot while still appearing to be deciding where to go. For this reason, decision time was just one measure, that of time spent on the location dot and usually included time taken to turn.

Instructions for the two map-following conditions emphasized that participants were not to begin moving to the next location until the direction choice had been completed. Nevertheless, the walking Time between dots was recorded because some of that time might be used for direction choices, checking accuracy of decisions, etc.

Results

The data were analyzed with the statistical package for microcomputers, Systat, Version 3.1. Multivariate analyses were carried out in all cases, but the univariate F statistic will be reported in this document whenever possible. When the program did not provide a univariate statistic, as in the analyses of more than two repeated measures, the multivariate statistic, Wilks' Lambda, will be reported.

Experiment 1

Several different analyses were computed on the map-following data. In the Variant condition, the participant was instructed not to turn the map while following the path and thus the map varied in relation to the room. In the Invariant condition, the participant was instructed to turn the map while following the route so the relationship of the map to the room did not vary. Preliminary analyses indicated no effect of map order (1,2,3,4,5,6 vs. 4,5,6,1,2,3) on the results, so all subsequent analyses were collapsed across map order.

Maps 1, 4, and 5 caused difficulty for some participants. This was because the starting dot was involved in more than one segment of the route (see Figure 2) and consequently, some subjects mistook the direction of the first segment. For example, on Map 1, the correct direction choice on dot 1 is a 45° turn to the right. Some subjects chose to go straight ahead along the path that should

have been used to return to the starting dot (segment 4). It was decided that if the subject chose to follow one of the paths radiating from the first dot, even if it was the incorrect one, the direction choice would be considered correct. As shown in Figure 1, the subjects who chose to go straight ahead on Map 1 usually completed the route by touching dots in the following order: 1, 4, 3, 2, 5(1), 6, 7. The completed pattern was the same as the correct one, but the sequencing of the dots was incorrect. In such cases, on Maps, 1, 4, and 5, the whole route was considered correct. In these instances, times on dots other than the first one, were not included in any data analyses because the direction and angle of turn associated with that path did not correspond to the experimenter defined turns.

Proportion Correct

For each map, a score of 1 was assigned if the map was successfully completed, while a score of 0 indicated that an error had been made. Thus, the proportion of people successfully completing the route was the measure of interest. A $2 \times 2 \times 2 \times 6$ (Age x Sex x Condition x Map) Analysis of Variance (ANOVA) was computed on these data with Condition and Map as within subject variables. The main effect of Age was reliable, $F(1, 60) = 15.37, < .001$, MS error = .37 with a larger proportion of the young (mean = .85) than elderly (mean = .68) persons successfully completing the maps. Sex also produced a reliable difference in performance, $F(1, 60) = 10.29, p < .003$, MS error = .37. Overall, more males (mean = .83) completed the routes

than did females (mean = .69). The instructional condition also produced a main effect, $F(1, 60) = 95.37, p < .001$, MS error = .18. The Variant condition in which the map was held constant in relation to the body of the subject was considerably more difficult (mean proportion completed maps = .62) than the Invariant condition (mean = .91) in which the map remained in constant orientation to the room. Finally, the main effect of the Map variable was reliable, $F(5, 300) = 7.48, p < .001$, MS error = .13. Participants had relatively little difficulty with the first three maps but the proportion of subjects successfully completing the latter maps was lower (means = .88, .82, .82, .73, .63, .72 for Maps 1-6 respectively).

The interaction between the Age and Map variables was reliable, $F(5, 300) = 2.47, p < .04$, MS error = .13. Figure 2 indicates that the pattern of the means for this interaction was such that there was little difference in the performance of the participants on Maps 1, 2, and 3 but substantial differences favouring the young on Maps 4, 5, and 6.

The Condition x Map interaction was also reliable, $F(5, 300) = 4.72, p < .001$, MS error = .098. As can be seen in Figure 3, this was due to the difficulty experienced by participants on Maps 4, 5, and 6 in the Variant condition.

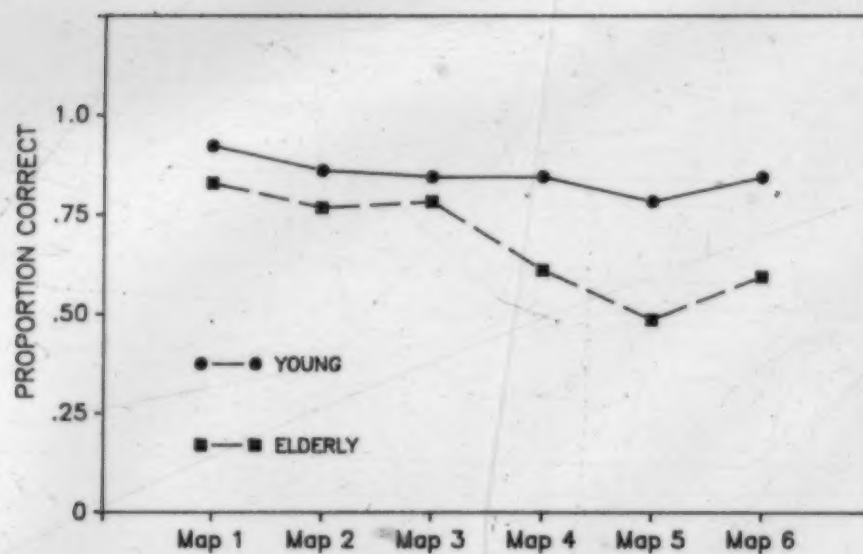


Figure 2. Proportion of young and elderly persons successfully completing each map

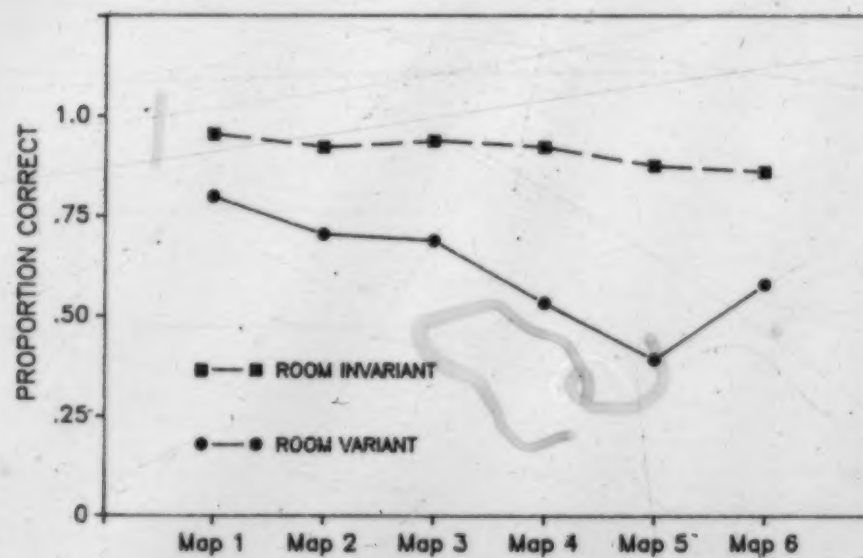


Figure 3. Proportion of subjects in the Variant and Invariant conditions successfully completing each map

Segments to First Error

The number of correctly completed route segments to the first error was analyzed in a $2 \times 2 \times 2 \times 6$ (Age $\times$ Sex $\times$ Condition $\times$ Map) ANOVA with Condition and Map as within subject measures. A statistically reliable main effect of Age resulted, $F(1, 60) = 18.38$, $p < .001$, MS error = 9.44, with young persons completing more segments than elderly persons (mean segment total over all maps = 50.67 young, 46.47 elderly). Males (mean = 46.59) completed significantly more segments than females (mean = 42.38), $F(1, 60) = 9.98$, $p < .003$, MS error = 9.44. Condition exerted a reliable influence, $F(1, 60) = 71.99$, $p < .001$, MS error = 4.95, such that participants completed more segments in the Invariant condition (mean = 48.57) than in the Variant condition (mean = 40.40). The Map effect was also reliable $F(5, 300) = 64.29$, $p < .001$, MS error = 3.32, with subjects completing an increasing number of segments over subsequent maps (means = 5.63, 6.32, 7.09, 7.92, 8.27, and 9.12 respectively). This effect is of little interest because the maximum possible number of segments increased with subsequent maps.

The Age $\times$ Map interaction was reliable, $F(5, 300) = 5.08$, $p < .001$, MS error = 3.32. Post-hoc contrasts assessing the simple main effects indicated that elderly persons completed significantly fewer segments than young people on Map 4, $F(1, 60) = 5.58$, $p < .03$, Map 5, $F(1, 60) = 18.59$, $p < .001$, and Map 6, $F(1, 60) = 14.86$, $p < .001$. Means for maps 1-6 respectively are Young: 5.82,

5.53, 7.41, 8.34, 9.09, 10.14; Elderly: 5.44, 6.11, 7.03, 7.50, 7.45, 8.09.

The reliable interaction between Condition and Map, $F(5, 300) = 7.11$, $p < .001$, MS error = 2.56, is illustrated in Figure 4. When participants turned the map to keep it aligned with the room (Invariant condition), near-ceiling performance was reached on all but the last two maps. Post-hoc contrasts indicated that the Variant condition resulted in the completion of significantly fewer segments on all maps, smallest $F(1, 60) = 10.14$, $p < .003$, MS error = 1.21.

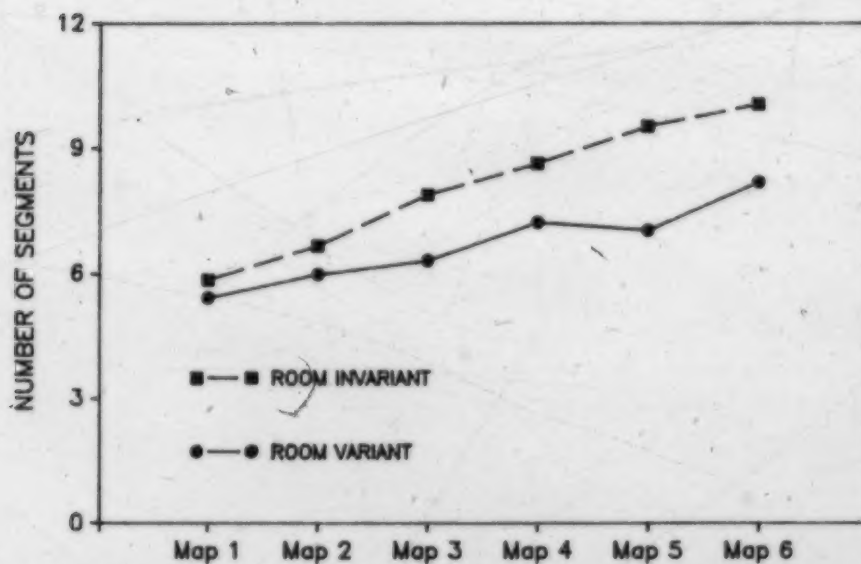


Figure 4. Number of segments to the first error for each map in the Variant and Invariant conditions. Note: Maximum number of segments across the six maps is 6, 7, 8, 9, 10, and 11.

Time Analyses

Mean times (in seconds) spent on each dot were computed for males and females within each age group. Any times exceeding twice the mean were deleted from the analyses. In the Variant condition, 6.8% of the dot times were deleted and in the Invariant condition 6.6% of the dot times were deleted. This procedure, which is common practice in reaction time research, ensured that extreme scores did not unduly influence the analyses. Only dot times that resulted in correct direction choices were included in the time analyses.

Dot 1 Times. Time spent on the first dot of each map appeared to have been used by most participants for orienting to the map as well as for making a decision for the first direction. For this reason, the first dots on each map were considered together in a separate analysis. Included in this analysis were the Dot 1 times for those subjects who had misunderstood the direction of the first dot but had completed a pattern that mirrored the correct route. A $2 \times 2 \times 2 \times 6$ (Age $\times$ Sex $\times$ Condition $\times$ Map) ANOVA was computed on the Dot 1 time data. Reliable main effects included Age, Sex, Condition, and Map (smallest $F(5, 300) = 8.23, p < .001$, MS error = 3.23. Elderly persons spent more time on the first dot than did young people (means = 5.73, 3.27, respectively) and females took longer than males (means = 5.09, 3.9, respectively). Times were faster in the Invariant than the Variant condition (means = 4.85, 4.14). First dot times were inconsistent across maps (Maps 1-6 means = 4.22, 3.92, 5.14, 4.83,

4.66, 4.22).

Interactions that were statistically reliable included Age x Map, $F(5, 300) = 3.08$, $p < .02$, MS error = 3.23, and Age x Sex x Map, $F(5, 300) = 3.58$, $p < .05$, MS error = 3.23. As Figure 5 illustrates, the young people used similar amounts of time for the first dot of each map. The elderly persons were consistently slower than young people and evidenced much greater variability across maps. Females in each age group took more time than males of the same age group, with the elderly females strongly influencing the results. A Sex x Condition x Map interaction was reliable, $F(5, 300) = 3.53$, $p < .005$, MS error = 2.97 and was primarily due to the performance of the elderly females on Map 3 of the Variant condition.

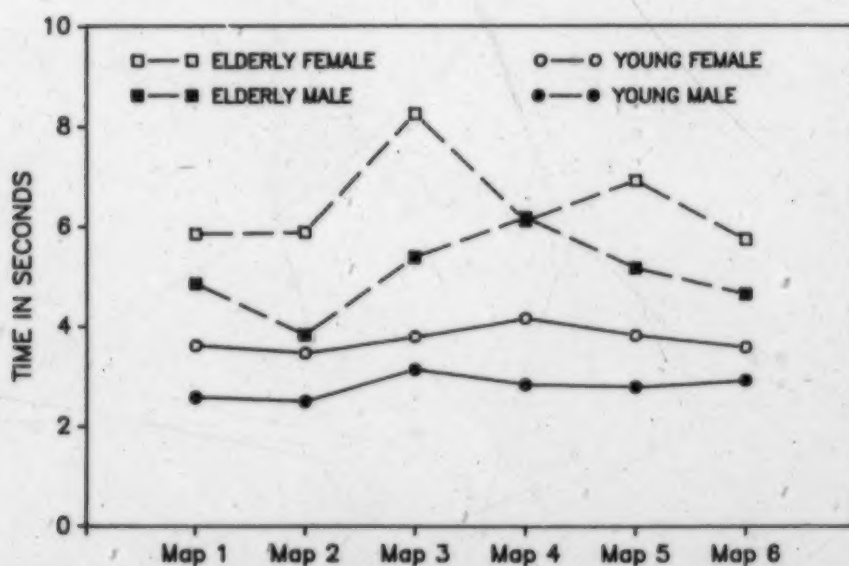


Figure 5. Age and sex differences for time on the first dot of each map collapsed over Variant and Invariant conditions.

Body Dot Time. The time spent on each dot was presumed to reflect direction choice decision time. There are a number of ways to look at this decision time. One way is to relate it to the direction of body turn and the number of degrees of turn in that direction that are required if the person makes a correct decision, herein called Body Dot time. To calculate this measure, a composite time for each subject was created for each of the possible body turns, 45° left and right, 90° left and right, and 135° left and right. This was accomplished by averaging, across the six maps, all Body Dot times that fit into each turn category. Whenever there was missing data for any particular subject, the average time on that item for all subjects within that group and sex was substituted. As can be seen in Table 3, calculation of each Body Dot time category involved averaging the dot times listed in the appropriate column.

A $2 \times 2 \times 2 \times 2 \times 3$ (Age x Sex x Condition x Right-Left x Degree) ANOVA, with the latter three being repeated, was computed on the Body Dot times. Consistent with the Proportion Correct and Segments to First Error analyses, the main effects of Age, Sex, and Condition were reliable, smallest $F(1, 60) = 16.76$, $p < .001$, MS error = 53.61. The older participants spent more time on each dot than did young people (Old = 2.33 Young = 1.19), as did the females compared to males (Female = 2.04, Male = 1.49). The Variant condition (mean = 2.03) resulted in longer times than were obtained for the Invariant Table 3 condition (mean = 1.49). The within subject main effects of Right vs.

Table 3

Differentiation of Dot orientation by Direction and Degree of Body Turn and by Degrees of Map Misalignment

Direction and Degrees of Body Turn						
Degrees Misalign.	45° R	45° L	90° R	90° L	135° R	135° L
0°	Map1-1	Map4-3 Map5-1 Map5-10 Map 6-9	Map3-3 Map4-1 Map6-1 Map6-5	Map2-1 Map2-3	Map3-1	Map1-3
45°		Map1-2 Map4-4 Map6-10			Map5-2 Map5-4	Map3-8
90°			Map1-6 Map2-2 Map3-4 Map4-9 Map5-5	Map4-2 Map5-9 Map6-4 Map6-8	Map2-7 Map3-7 Map5-7 Map6-2 Map6-6	Map2-4 Map4-5 Map4-7 Map5-3 Map6-11
135°	Map2-5 Map3-6	Map1-4			Map4-6 Map4-8	Map3-2 Map5-8 Map6-3 Map6-7
180°	Map3-5		Map2-6	Map5-6	Map1-5	

Note: Map number is followed by dot number; ie. Map 1-3 designates the third dot of the route outlined on Map 1.

Note: Except for the specific analysis of Dot 1 times, the first dots on each route were not included in any time analyses.

Left turn and Degree of body turn were also reliable. Right turns (mean = 2.0) required more time than did left turns (mean = 1.59), $F(1, 60) = 66.45$, $p < .001$, MS error = 5.89. Ninety degree turns required the least amount of time (mean = 1.48) followed by 45° (mean = 1.72) and 135° turns (mean = 2.19), Wilks' Lambda (2, 59) = .433, $p < .001$.

Several interactions were reliable including Age x Sex, Sex x Condition, Age x Right-Left, Sex x Right-Left, Age x Sex x Right-Left, Condition x Right-Left, and Sex x Condition x Right-Left (smallest $F(1, 60) = 4.8$; $p < .04$, MS error = 53.61). Other interactions also reliable included Age x Degree, Sex x Degree, Condition x Degree, Right-Left x Degree, and Condition x Right-Left x Degree (largest Wilks' Lambda (2, 59) = .870, $p < .02$). All of these interactions occurred as a result of the extreme performance of the elderly females.

Body Segment Time. Extreme scores in the segment time data were deleted in the same manner as dot times. In the Variant condition .01% of segment times were deleted and in the Invariant condition .002% were deleted.

Time taken to walk the various segments between dots should be similar for each subject if, in fact, all the decision making took place while the subject was standing on the dot. If some of the decision making, decision checking etc. took place while the subject walked between dots, the segment times should show the same patterns

as the dot times. To assess this possibility, the Body Segment times were computed from the same dot combinations as were used to calculate Body Dot times.

A $2 \times 2 \times 2 \times 2 \times 3$ (Age $\times$ Sex $\times$ Condition $\times$ Right-Left $\times$ Degree) ANOVA was computed on the Body Segment time data. Reliable differences resulted for Degree, Wilks' Lambda (2, 59) = .903, $p < .05$, and Age $\times$ Right-Left $\times$ Degree, Wilks' Lambda (2, 59) = .901, $p < .05$. Table 4 illustrates that for both groups the pattern among the segment times for Right turns is very similar to the pattern for the corresponding dot times.

Table 4

Experiment 1: Mean Dot and Segment Times
for Degrees of Body Turn (in sec.)

Degrees	Young		Elderly	
	Dot	Segment	Dot	Segment
R45°	1.44	1.41	3.0	1.84
R90°	.97	1.28	1.9	1.73
R135°	1.73	1.50	3.0	1.94
L45°	.84	1.39	1.61	1.79
L90°	1.14	1.31	1.91	1.69
L135°	1.46	1.49	2.58	1.94

Elderly persons' times are longer than those of the young people, and the times for each degree category reflect the same order as the

Body Dot times: 90° , 45° , 135° . The segment times for Left turns do not match the 45° - 90° - 135° order of the Body Dot time data. Instead, the times for 45° and 90° are very similar but increases do occur on the 135° segments. The segment times are not uniform as would be expected if no decision making was taking place during walking. It is quite likely that some planning or checking was occurring while subjects walked between dots. However, most variables and their interactions did not show reliable effects for the segment walking times. This indicates that, although not completely successful, the instructions mostly restricted the influence of decision variables to Body Dot times.

North Dot Times. Another way to look at dot time is to relate it to the number of degrees that the map is misaligned to the North wall at the time the decision is made, herein called North Dot time. In the Variant condition, alignment of the map changed as the subject walked along the route. Thus, the subject was required to mentally rotate the map to realign it with the North wall. In the Invariant condition, no mental rotation was required, but physical rotations of the map were carried out in order to keep it aligned with the North wall of the room. Five North misalignment categories were calculated by averaging the appropriate dots across the six maps. These turn categories were 0° , 45° , 90° , 135° , and 180° and were calculated in the same manner as the Body Dot times. For example, as Table 3 (pg. 37) indicates, the 180° misalignment category was calculated for each

subject by averaging, across the table, the decision times on Map3 Dot5, Map2 Dot6, Map5 Dot6, and Map1 Dot5. Other misalignment categories were calculated in the same manner.

Although the primary focus of interest for this analysis was the influence of map misalignment, there were other variables that might have been contributing to performance in the Variant condition. Besides the body turn for each dot, there was the possibility that the location of each dot within the sequence of a map and the number of segments touching any one dot might have influenced performance. A control set of categories was created from the Invariant condition dot times, all of which were aligned with North. These control categories were made up of an equal number of dots with the same body turns as those in the Variant condition categories so that body turn remained the same but all other influences were randomized. This was done by ensuring that, whenever possible, the same dots used in the Variant category were not used in the corresponding Invariant control category. For example, the Invariant control for 180° misalignment included the following dots: Map2 Dot2, Map2 Dot5, Map5 Dot9, Map6 Dot6. None of these dots were in the same category, Variant condition, but each matched the dots from that category in terms of Body turn orientation.

A 2 x 2 x 2 x 5 (Age x Sex x Condition x Degree) ANOVA was computed on the North time data. As in the previous analyses, the main effects of Age, Sex, and Condition were reliable (smallest $F(1,$

60) = 18.21, $p < .001$, MS error = 3.75). Elderly persons (mean = 2.58) took more time than young people (mean 1.33), as did females (mean = 2.25) compared to males (mean = 1.67), and the Variant condition (mean = 2.29) was more demanding than the Invariant control condition (mean = 1.62). The main effect of Degree was also reliable, $F(4, 240) = 56.89$, $p < .001$, MS error = .69. Times were similar for 0° and 45° of map misalignment but began to increase with 90° and were much longer with the 135° and 180° angles (means = 1.37, 1.34, 1.63, 2.41, 2.83, respectively). The Age x Condition x Degree interaction was reliable, $F(4, 240) = 8.39$, $p < .001$, MS error = .85, as was Condition x Degree, $F(4, 240) = 59.5$, $p < .001$, MS error = .85. Figure 6 illustrates that, in the Variant condition for both age groups, greater misalignment of the map resulted in increased decision times. The effect was much stronger for elderly persons than for young people when misalignment was greater than 45° .

The reliable interaction between Age, Sex, and Degree is illustrated in Figure 7, ($F(4, 240) = 3.01$, $p < .02$), MS error = .69. Elderly females took longer and had more difficulty with the more acute angles than did elderly males or young people. The influence of the elderly females was responsible for several other interactions, including Age x Sex, Age x Degree, Sex x Degree, Sex x Condition, Sex x Condition x Degree, and Age x Sex x Condition x Degree, smallest $F(4, 240) = 2.71$, $p < .04$, MS error = .85.

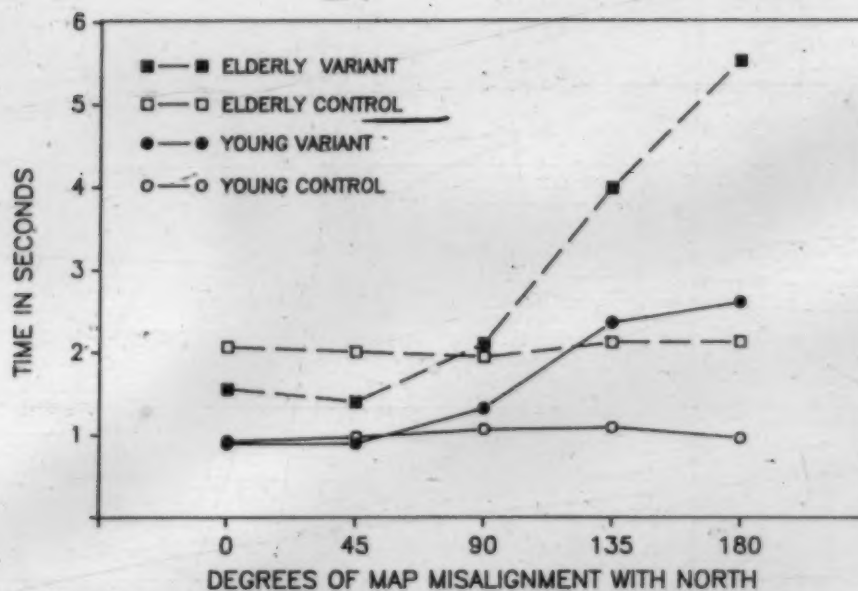


Figure 6. Age differences on decision times for degrees of map misalignment: variant condition compared to invariant control. Note: Invariant control categories were all at 0° misalignment.

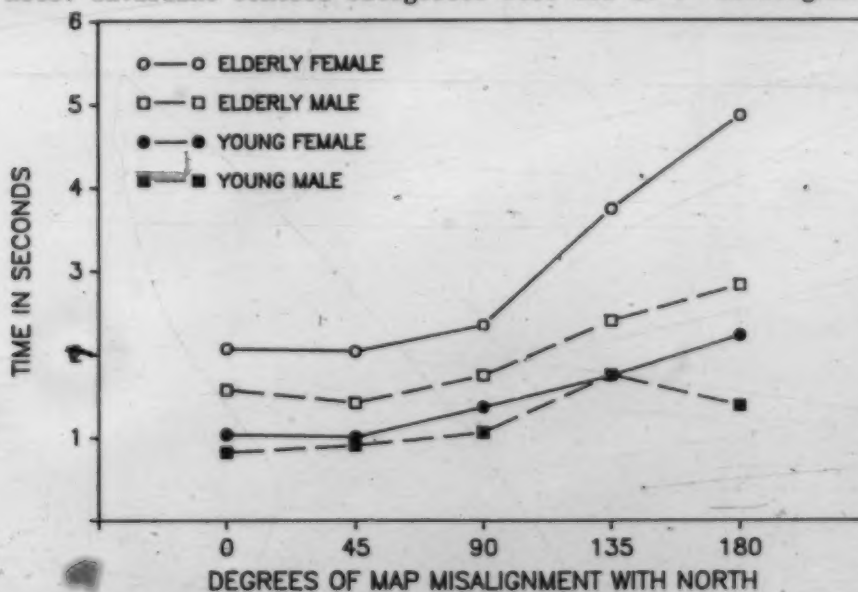


Figure 7. Age and sex differences on decision times for degrees of map misalignment collapsed over conditions.

North Segment Time. Time spent walking from dot to dot had been found to involve some decision making in the previous analyses of the influence of body direction and degrees of turn. In the same way, some of the walking time may have been used for decision making in relation to degrees of map misalignment. Therefore, North segment time categories were calculated in the same manner as North misalignment dot categories. A $2 \times 2 \times 2 \times 5$ (Age x Sex x Condition x Degree) ANOVA of the North Segment times resulted in reliable main effects including Age, Condition, and Degree, (smallest $F(4, 240) = 11.76$, $p < .001$, MS error = .02). Older people (mean = 1.84) took longer to walk the segments than did young people (mean = 1.41), females (mean = 1.69) took more time than males (mean = 1.55), and times were longer in the Variant condition (mean = 1.69) than in the Invariant condition (mean = 1.56). The Condition x Degree interaction was reliable, $F(4, 240) = 24.63$, $p < .001$, MS error = .03, and was primarily due to the sharp increase in time for the 180° segment time in the Variant condition (means from 0° to 180° = 1.67, 1.56, 1.71, 1.65, 1.84). Times changed very little over degree sizes in the Invariant control condition (means = 1.56, 1.5, 1.52, 1.64, 1.51). There was a reliable interaction between Age and Degree, $F(4, 240) = 3.57$, $p < .01$, MS error = .02. The means for this analysis are shown in Table 5. There was little change in segment time over degree sizes for the young people. Elderly persons were less consistent in their walking times and took longer on the 180° misalignment segments than

on the other degree sizes. As with Body segment times, these data suggest that, for the elderly persons at least, segment times were often used for decision making.

Table 5

Experiment 1: Mean Dot and Segment Times for
Degrees of Map Misalignment With North (in sec.)

Degrees	Young		Elderly	
	Dot	Segment	Dot	Segment
0°	.931	1.399	1.833	1.835
45°	.958	1.378	1.724	1.751
90°	1.214	1.398	2.045	1.838
135°	1.745	1.441	3.072	1.845
180°	1.804	1.428	3.848	1.923

North-Body Dot Time Combinations. As the previous analyses indicated, body turn and map misalignment influence direction decision time. However, the Body and North time analyses did not assess any possible interactions between these variables in the Variant condition. One might expect that the more acute body turns, especially 135° , would require longer decision times at greater degrees of map misalignment than the smaller body turns. Because not all possible combinations of body turn and map misalignment were represented across the six maps (Table 3, pg. 37), it was not possible to use analysis of variance procedures to test for such an interaction. Figure 8 illustrates the dot times of the body-turn/north-misalignment combinations that are represented by the data. The times have been divided into three sets for each degree size of body turn. Graphed within each set are the body degree sizes in combination with increasing degrees of map misalignment. There is a very obvious influence of map misalignment shown in the higher times for the 135° and 180° of misalignment for the three body turn categories. This trend reflects that seen in the previous analysis of North Dot times. The influence of increasing angles of body turn, although not very strong, is also apparent. This is particularly noticeable for the 135° body turns which required longer times than the 45° and 90° body turns in comparable map misalignment combinations which indicates an interaction between body turn and map misalignment.

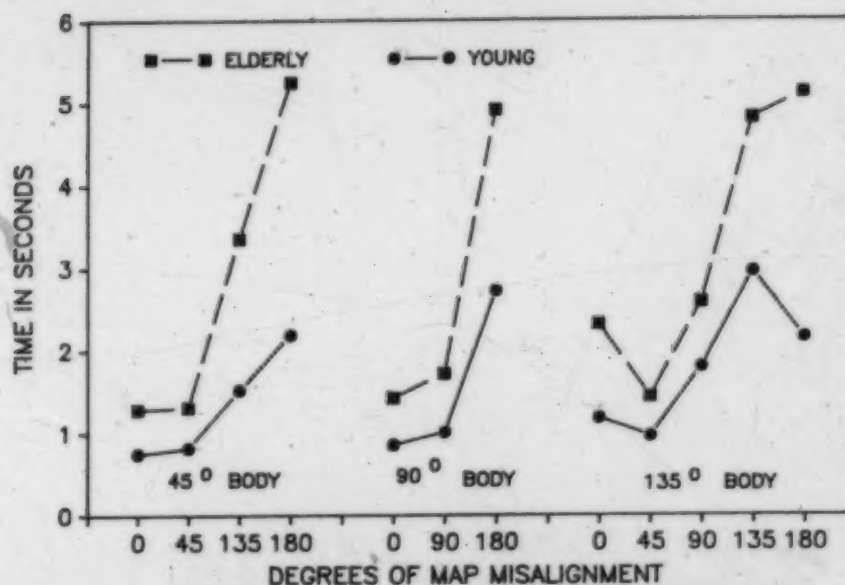


Figure 8. Young and elderly times on combination body dot/ north misalignment turns collapsed over right-left body turn.

Verbal Maze

Map 6 was presented to participants in a verbal form in order to reduce the influence of memory on the accurate completion of the map. In one condition, External-Verbal, participants were given direction instructions in relation to the external coordinates of the compass. In the Body-Verbal condition, instructions were given in terms of right-left direction and number of degrees of body turn.

As had been done for the map following data, a score of 1 or 0 was assigned depending on success at completing the route which yielded a measure of proportion of participants successfully completing the route. The number of segments to first error was also computed. Analyses were carried out assessing performance on Map 6 for the two verbal and

two map following conditions. A $2 \times 2 \times 4$ (Age x Sex x Condition) ANOVA on the Proportion Correct data resulted in a reliable effect of Condition, $F(3, 177) = 15.12$, $p < .001$, MS error = .16. The smallest proportion of participants completed Map 6 in the Body-Verbal condition followed by the Variant-Map, the External-Verbal, and the Invariant-Map conditions (means = .46, .59, .83, and .87 respectively). Age had a reliable influence on performance, $F(1, 59) = 8.85$, $p < .005$, MS error = .23 with a greater proportion of young people (mean = .77) completing the map over all conditions than older persons (mean = .58). More males (mean = .76) completed the map than females (mean = .60), $F(1, 59) = 6.04$, $p < .02$, MS error = .23.

The $2 \times 2 \times 4$ (Age x Sex x Condition) ANOVA on Segments to First Error resulted in significant main effects of Age, $F(1, 59) = 7.343$, $p < .01$, MS error = 15.35, and Sex, $F(1, 59) = 8.41$, $p < .006$, MS error = 15.35. Older persons completed fewer segments than younger people (means = 7.88, 9.34), and males succeeded more often than females (means = 9.38, 7.84). The effect of condition was reliable, $F(3, 177) = 12.93$, $p < .001$, MS error = 9.86 with the most segments completed in the Invariant-Map condition followed by the External-Verbal, Variant-Map, and the Body-Verbal condition (means = 10.19, 9.41, 8.22, and 6.95 respectively).

In order to compare decision times, an average dot time was computed for Map 6 of each condition. A $2 \times 2 \times 4$ (Age x Sex x Condition) ANOVA was carried out with six cases deleted due to missing

data. As in the other two analyses, Age, Sex, and Condition were reliable, smallest $F(1, 54) = 15.47, p < .001$, MS error = 2.26. Older people took more time than younger persons (means = 3.04, 1.71) and females took longer than males (means = 3.01, 1.95). Time taken for the Body-Verbal condition was the longest, followed by the Variant-Map, Invariant-Map, and the External-Verbal conditions (means = 2.83, 2.63, 1.85, 1.79). Reliable interactions included Age x Sex, $F(1, 54) = 7.55, p < .01$, MS error = 2.26 and Sex x Condition, $F(3, 162) = 3.82, p < .02$, MS error = .87. Both of these interactions were due to the longer times taken by the elderly females. A reliable Age x Condition interaction, $F(3, 162) = 5.83, p < .002$, MS error = .87 resulted because there were consistent age differences across all conditions except in the External-Verbal condition for which both age groups took similar amounts of time.

As well as examining the relationships among the four map conditions, some analyses were carried out on each of the two verbal conditions. Times spent on each dot were categorized according to direction in the same manner as Body and North dot times were computed for the map following data. Because only Map 6 was used, not all types of turns were included in the External-Verbal condition; there were no South or Northeast turns. In the Body-Verbal condition, the turn categories that could be analyzed included 45° , 90° , and 135° , but right versus left differences could not be assessed.

A $2 \times 2 \times 6$ (Age x Sex x Direction) ANOVA was computed on the dot

time data for the External-Verbal condition. Age was reliable, $F(1, 60) = 12.02$, $p < .002$, MS error = 1.65, with older persons (mean = 2.06) taking more time than young people (mean = 1.6). Females (mean = 1.99) took longer than males (mean = 1.66), $F(1, 60) = 6.22$, $p < .02$, MS error = 1.65. Direction also had a reliable influence on results, $F(5, 300) = 76.23$, $p < .001$, MS error = .35. Participants had more difficulty with the oblique coordinates of the compass than with the cardinal coordinates, (N = 1.11, E = 1.76, W = 1.21, SE = 2.19, SW = 2.84, NW = 1.86). The interaction between Age, Sex and Direction was reliable, $F(5, 300) = 3.27$, $p < .01$, MS error = .35. The performance of the elderly females accounted for this and the other reliable interactions, Age x Direction, $F(5, 300) = 3.09$, $p < .04$, MS error = .35, and Sex x Direction, $F(5, 300) = 5.65$, $p < .001$, MS error = .35.

A $2 \times 2 \times 3$ (Age x Sex x Degree) ANOVA on the Body-Verbal data resulted in reliable main effects of Age, $F(1, 60) = 33.16$, $p < .001$, MS error = 2.0 and Sex, $F(1, 60) = 41.93$, $p < .001$, MS error = 2.0. Elderly persons took more time (mean = 3.61) than young people (mean = 2.43) and females (mean = 3.68) took longer than males (mean = 2.36). Degree had a reliable influence, $F(2, 120) = 38.48$, $p < .001$, MS error = 1.11 with 135° turns requiring the most time (mean = 3.81), followed by 45° (mean = 3.06) and 90° (mean = 2.18) turns. As with the analysis of the data from the External-Verbal condition, reliable interactions that resulted from this analysis were due to the

influence of the elderly females. These interactions included Age x Sex, Age x Degree, and Age x Sex x Degree, smallest $F(2, 120) = 6.09$, $p < .004$, MS error = 1.11.

Wayfinding Questionnaire

Separate 2×2 (Age x Sex) ANOVAs were computed on each question of the Wayfinding Questionnaire (Appendix B), with the exception of two questions. Subjects' answers to items regarding getting lost in familiar (Question 5) or unfamiliar (Question 7) environments when given explicit directions were dependent on their answers to the immediately preceding questions. Consequently, the number of subjects responding were insufficient for analyses. In answer to Question 2, older persons (mean = 2.31) reported a poorer sense of direction than young people (mean = 1.5), $F(1, 60) = 15.23$, $p < .001$, MS error = .69. There were no reliable age differences on any of the other questions. Sex differences were reliable for several questions, smallest $F(1, 60) = 4.15$, $p < .03$, MS error = .46. Females (mean = 1.91) rated their sense-of-direction at twenty years of age (Question 1) as poorer than males (mean = 1.44). Females (mean = 2.25) reported more difficulty identifying right from left (Question 3) than males (mean = 1.38). Females (mean = 2.53) also reported getting lost in unfamiliar surroundings (Question 6) more often than males (mean = 2.19).

In order to provide some information about the relationship between judged competence of wayfinding and actual performance,

several correlations were calculated. The performance measures included a Total Proportion Correct (1 = perfect completion of a route) and a Total Segments to First Error measure computed across the six maps of the map following task for the Variant and Invariant conditions. Other measures included the dot times for direction and degrees of body turn (Body Dot times) and those for map misalignment (North Dot times). From the verbal conditions, Proportions Correct and Segments to First Error were included. Pearson Correlation Coefficients were computed between these measures, and the Wayfinding questions. Only correlations over .40 were considered to be strong and these were found between sense-of-direction now (Question 2) and several of the time measures and are listed in Table 6. These correlations indicate that persons who rate their sense-of-direction as good took less time to make decisions than those people who gave poorer ratings.

Table 6

Experiment 1: Pearson Correlations Between Perceived
Sense-of-Direction and Body and North Dot Time Measures

Body Dot Measures				
	V-L45°	V-L135°	I-R135°	I-L135°
Correlation	.519	.463	.465	.471

North Dot Measures						
	V-N45°	V-N90°	V-N180°	I-N0°	I-N45°	I-N180°
Correlation	.419	.420	.435	.490	.468	.413

Note: V - Variant, I - Invariant, L, R - Left, Right body turn,
N - North Misalignment

Note: All correlations are significant, $p < .001$.

Experiment 2

Analyses on the data from Experiment 2 were completed using the same variables as in the first experiment. Preliminary analyses indicated no effect of map order on the results, so all subsequent analyses were collapsed across map order.

Proportion Correct

A score of 1 was assigned if a route had been successfully completed; 0 indicated an incomplete route. A $2 \times 2 \times 2 \times 6$ (Group x Sex x Condition x Map) ANOVA was computed on these data with Condition and Map as within subject measures. Results indicated statistically reliable effects of Condition, $F(1, 60) = 65.63$, $p < .001$, MS error = .22 and Condition x Map, $F(5, 300) = 4.08$, $p < .002$, MS error = .09. A smaller proportion of subjects completed the routes in the Variant condition (mean = .70) than in the Invariant condition (mean = .97) with Maps 4, 5, and 6 of the Variant condition causing more difficulty than other maps (Variant Map 1-6 means = .84, .75, .72, .59, .61, .67; Invariant Maps 1-6 means = .94, .98, .97, .98, .97, .97).

Segments to First Error

A $2 \times 2 \times 2 \times 6$ (Group x Sex x Condition x Map) ANOVA was computed on the segment data with Condition and Map as within subject measures. Statistically reliable main effects included Condition, $F(1, 60) = 46.57$, $p < .001$, MS error = 4.93 (Variant mean = 7.25, Invariant mean = 8.34) and Map, $F(5, 300)$, $p < .001$, MS error = 2.21 (Map 1-6 means

- 5.68, 6.62, 7.37, 8.15, 9.04, 9.93). As well, a reliable interaction occurred between Condition and Map, $F(5, 300) = 7.58$, $p < .001$, MS error = 1.97. Participants reached near ceiling performance on all maps of the Invariant condition (Map 1-6 means = 5.72, 6.89, 7.88, 8.92, 9.78, 10.88) whereas in the Variant condition performance declined noticeably on Maps 4, 5, and 6 (Map 1-6 means = 5.64, 6.34, 6.86, 7.38, 8.3, 8.98).

Time Analyses

Mean times (in seconds) spent on each dot were calculated for males and females within each group. Any times exceeding twice the mean were deleted from the analyses. In the Variant condition 3.5% of dot times were deleted and 4.4% in the Invariant condition. Segment times deleted included .12% in the Variant condition and .06% in the Invariant condition.

Dot 1 Times. As noted in Experiment 1, participants seemed to be using time on the first dot of each map to scan the route and orient to the map as well as make a decision regarding the first direction. For this reason, time on the first dot of each map was analyzed separately in a $2 \times 2 \times 2 \times 6$ (Group x Sex x Condition x Map) ANOVA. Times in the Variant condition (mean = 3.84), were reliably longer than in the Invariant condition (mean = 3.16), $F(1, 60) = 35.1$, $p < .001$, MS error = 2.48. Map exerted a reliable effect, $F(5, 300) = 5.02$, $p < .001$, MS error = 1.74 and was due mainly to faster times on Maps 2 and 6 (Map 1-6 means = 3.62, 3.03, 3.62, 3.68, 3.70, 3.35).

Also reliable was the Group x Sex interaction, $F(1, 60) = 4.09, p < .05$, MS error = 10.94. As Figure 9 indicates, the Group x Sex differences were due primarily to the performance of the normal males who were consistently faster on all maps than any other group. (The ordinate on Figure 9 has been set to match that used on the corresponding Figure 5 in Experiment 1).

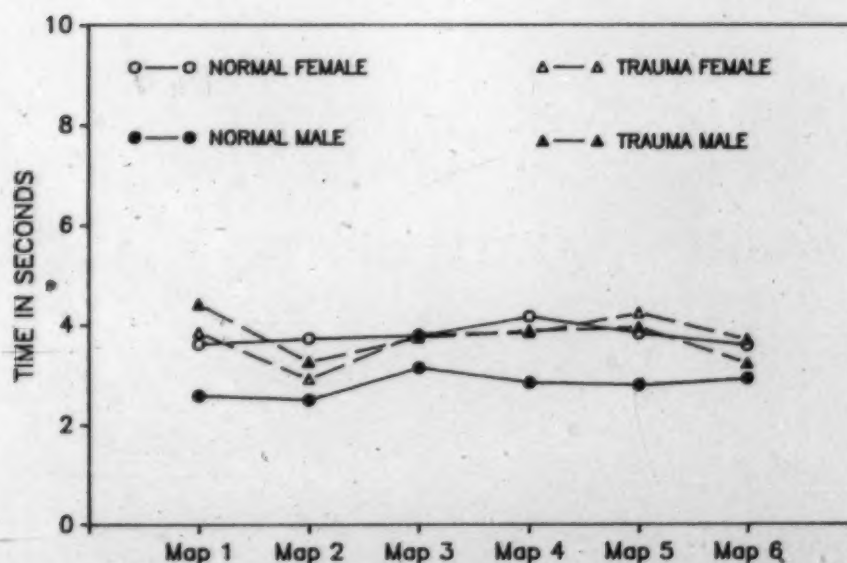


Figure 9. Time on the first dots of each map for head injured (trauma) and control subjects, collapsed over Variant and Invariant conditions.

Body Dot and Segment Times. In these analyses, decision time was assessed in relation to the required direction of body turn (right/left) and number of degrees of turn on each location dot independent of map misalignment. Body Dot and Segment time categories were computed in the same way as in Experiment 1. A $2 \times 2 \times 2 \times 2 \times 3$ (Group x Sex x Condition x Right-Left x Degree) ANOVA on the Body Dot time data resulted in no reliable effects.

A $2 \times 2 \times 2 \times 2 \times 3$ (Group x Sex x Condition x Right-Left x Degree) ANOVA was carried out on the Body Segment time data. No reliable main effects emerged from this analysis, although several interactions were significant. These included Condition x Right-Left, $F(1, 60) = 5.1, p < .03$, MS error = .18, Group x Condition x Right-Left, $F(1, 60) = 4.43, p < .05$, MS error = .18, Condition x Right-Left x Degree, Wilks' Lambda (2, 59) = .86, $p < .02$, and Group x Condition x Right-Left x Degree, Wilks' Lambda (2, 59) = .88, $p < .001$. Figure 10 illustrates the latter four-way interaction. The patterns evident in these data indicate that participants were using some of the segment time to make decisions and that these were influenced by direction, degree of turn, condition, and group membership.

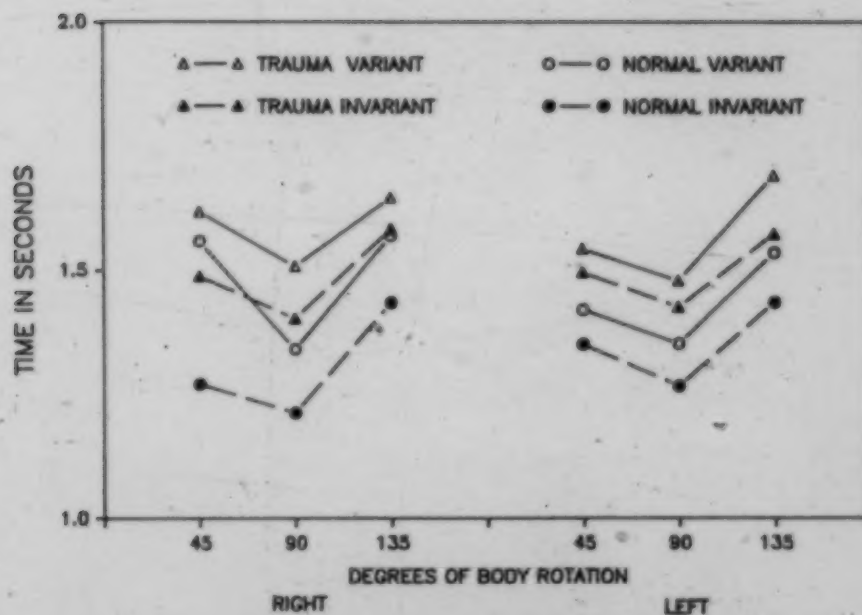


Figure 10. Body segment times for head injured (trauma) and normal subjects, Variant and Invariant conditions.

North Dot and Segment Times. The variable of interest in these analyses was the influence of map misalignment on decision time (North Dot and Segment times). A $2 \times 2 \times 2 \times 5$ (Group $\times$ Sex $\times$ Condition $\times$ Degree) ANOVA was computed on the North Dot time categories which were calculated in the same manner as in Experiment 1. Head injured subjects took longer (mean = 1.99) than normals (mean = 1.33), $F(1, 60) = 17.26$, $p < .001$, MS error = 4.12. Degree of map misalignment had a reliable effect, $F(4, 240) = 72.77$, $p < .01$, MS error = .52 with longer times over increasing degrees (means in ascending order -

1.13, 1.23, 1.50, 2.04, 2.41). Times were longer in the Variant condition (mean = 2.05) than in the Invariant control condition (mean = 1.27), $F(1, 60) = 115.89$, $p < .001$, MS error = .84. There was a reliable interaction between condition and degree, similar to that seen in Experiment 1, $F(4, 240) = 74.85$, $p < .001$, MS error = .54. The times across degree sizes in the Invariant control condition were fairly uniform (means for $0^\circ - 180^\circ = 1.18, 1.36, 1.28, 1.39, 1.17$, respectively) while in the Variant condition times increased linearly with degree size, steeper increases occurring on the last two (means = 1.09, 1.11, 1.73, 2.7, 3.64). A reliable interaction occurred between group and condition, $F(1, 60) = 5.44$, $p < .03$, MS error = .84 due to much longer times taken by the head injured group in the Variant condition (Variant means: Normal = 1.52, Trauma = 2.23; Invariant means: Normal = 1.01, Trauma = 1.39). Figure 11 illustrates the reliable interaction between Group and Degree, $F(4, 240) = 5.94$, $p < .001$, MS error = .52. The head injured participants took longer than the normal control subjects for all degree categories with a sharp increase occurring at 180° of misalignment.

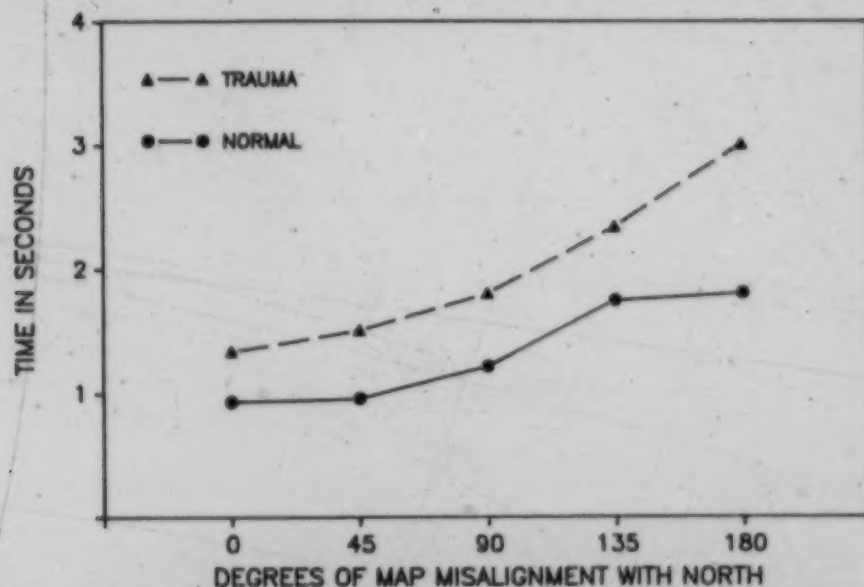


Figure 11. Decision times for degrees of map misalignment for head injured and normal subjects, collapsed over conditions.

Note: Map misalignment only occurred in the Variant condition, in the Invariant condition maps were always aligned with North.

The results of a $2 \times 2 \times 2 \times 5$ (Age x Sex x Condition x Degree) ANOVA of the North Segment times resulted in a reliable main effect of Group, $F(1, 60) = 4.68$, $p < .04$, MS error = .72. Trauma subjects (mean = 1.55) took longer than normal persons (mean = 1.41). Variant condition times (mean = 1.53) were longer than Invariant times (mean = 1.43), $F(1, 60) = 15.33$, $p < .001$, MS error = .09. Degree size had a reliable influence on performance, $F(4, 240) = 4.81$, $p < .002$, MS error = .02 (means 0° - 180° = 1.47, 1.48, 1.49, 1.47, 1.51). Significant interactions included Group x Degree, $F(4, 240) = 2.45$, $p < .05$, MS error = .01, and Condition x Degree, $F(4, 240) = 40.73$, $p < .001$.

.001, MS error = .01. Table 7 illustrates that the pattern of segment times is not very different from that seen for dot times. Head injured subjects took longer for all dots and segments than normals, reflecting the dot time trend of longer times for greater map misalignment.

Table 7

Experiment 2: Mean Dot and Segment Times for
Degrees of Map Misalignment With North (in sec.)

Degrees	Normal		Head Injured	
	Dot	Segment	Dot	Segment
0°	.93	1.40	1.34	1.54
45°	.96	1.38	1.50	1.53
90°	1.21	1.40	1.80	1.57
180°	1.80	1.43	3.01	1.59

North-Body Dot Time Combinations. Figure 12 shows the times of the body-turn/north-misalignment combinations from Experiment 2. Similar to the data of Experiment 1, the influence of map misalignment is shown in the higher times for the 135° and 180° of misalignment for all three body turn categories. This trend reflects that seen in the previous analysis of North Dot times. The influence of increasing angles of body turn, although not very strong, is also apparent. This

is particularly noticeable for the 135° body turns which are higher than the 45° and 90° body turns in comparable map misalignment combinations.

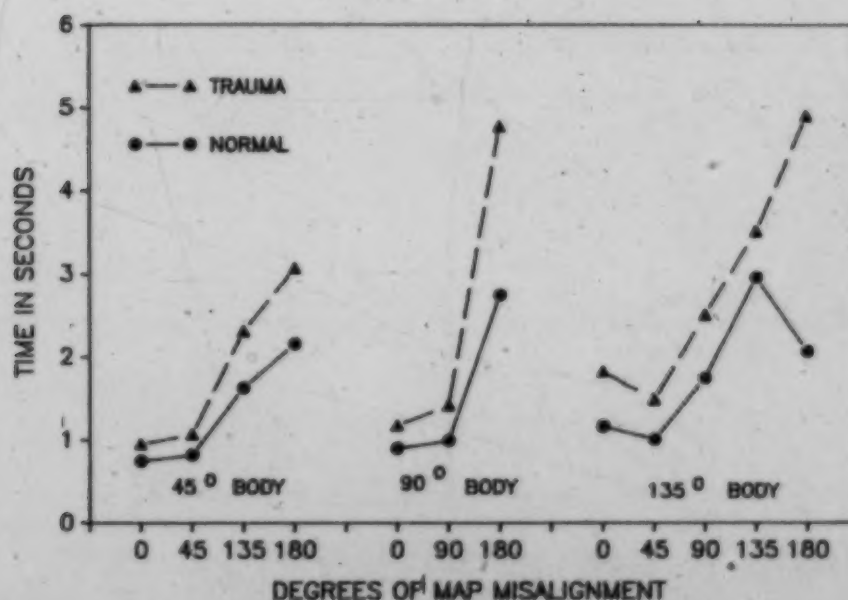


Figure 12. Variant condition times on composite turns collapsed over left and right body direction for head injured and normal persons.

Verbal Maze

Participants were presented with Map 6 in two verbal instruction formats. In the External-Verbal condition, instructions were given as compass coordinates and in the Body-Verbal condition the instructions were given in terms of right-left direction and degrees of body turn. A 2 x 2 x 4 (Group x Sex x Condition) ANOVA on the Proportion Correct data for Map 6 assessed differences across the map following and

verbal maze conditions. A smaller proportion of head injured persons successfully completed Map 6 (mean = .65) than normals (mean = .77), $F(1, 60) = 5.5$, $p < .03$, MS error = .19. The Body-Verbal condition (mean = .40) had the smallest proportion of subjects completing the map, followed by Variant-Map (mean = .68), External-Verbal (mean = .81), and Invariant-Map (mean = .97), $F(3, 177) = 25.23$, $p < .001$. The ANOVA on the segments to first error data resulted in a reliable effect of condition, $F(3, 177) = 18.67$, $p < .001$, MS error = 8.6. The fewest number of segments were completed in the Body-Verbal condition (mean = 7.02), followed by Variant-Map (mean = 8.95), External-Verbal (mean = 9.43), and Invariant-Map (mean = 10.87).

The $2 \times 2 \times 4$ (Group $\times$ Sex $\times$ Condition) ANOVA on average dot time was computed with eight subjects deleted because of missing data. There was a reliable effect of Group, $F(1, 52) = 14.17$, $p < .001$, MS error = 1.5, with normal subjects (mean = 1.71) taking less time than head injured persons (mean = 2.38). Condition was also reliable, $F(3, 156) = 25.1$, $p < .001$, MS error = .49. The most time was taken in the Body-Verbal condition (mean = 2.51), followed by Variant-Map (mean = 2.18), Invariant-Map (mean = 1.42), and External-Verbal (mean = 1.9).

Analyses were also conducted within each Verbal condition on categories created according to direction type. In the External-Verbal condition, categories included north, east, southeast, southwest, west, and northwest. In the Body-Verbal condition

categories were 45° , 90° , and 135° . A $2 \times 2 \times 6$ (Group $\times$ Sex $\times$ Direction) ANOVA was computed on the External coordinate data. Trauma subjects took more time (mean = 2.18) than normal subjects (mean = 1.6), $F(1, 60) = 19.34$, $p < .001$, MS error = 1.66. Direction exerted a reliable influence, $F(5, 300) = 71.68$, $p < .001$, MS error = .32, with the cardinal points of the compass generally taking less time than the obliques (means: N = 1.13, E = 1.87, W = 1.41, SE = 2.17, SW = 2.86, NW = 1.97). The Group $\times$ Sex $\times$ Direction interaction was also reliable, $F(5, 300) = 3.99$, $p < .003$, MS error = .32 and is illustrated in Figure 13. This interaction seemed to be due to differences in the performance of the two groups of males on the SE, SW, and NW directions.

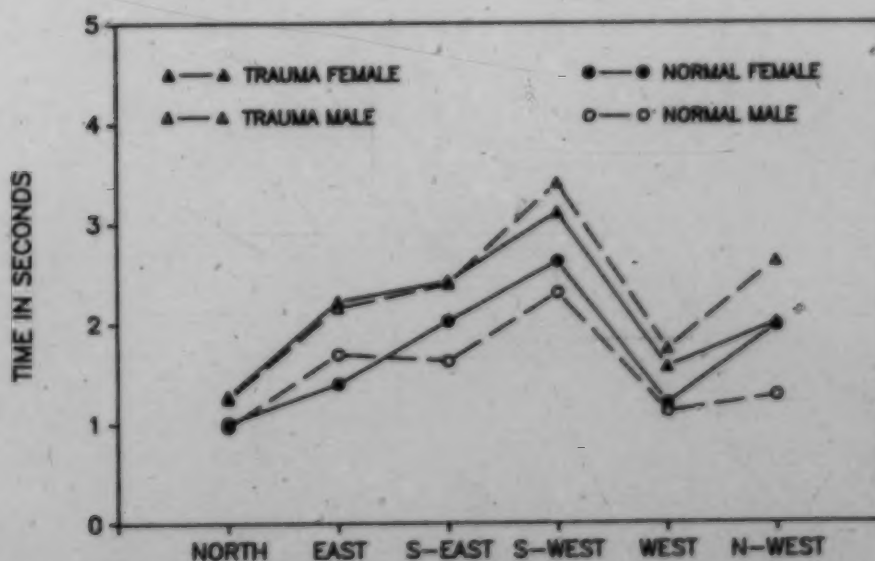


Figure 13. Decision times for external coordinate categories in the External-Verbal maze.

A 2 x 2 x 3 (Group x Sex x Degree) ANOVA on the Body-Verbal time categories resulted in significant differences between the groups, $F(1, 60) = 4.44$, $p < .04$, MS error = 2.67. Normals took less time (mean = 2.43) than trauma subjects (mean = 2.68). Sex exerted a reliable difference, $F(1, 60) = 4.24$, $p < .05$, MS error = 2.67, with females (mean = 2.92) taking longer than males (mean = 2.43). Ninety degree turns (mean = 2.05) took the least amount of time, followed by 45° (mean = 2.9) and 135° turns (mean = 3.08), $F(2, 120) = 19.47$, $p < .001$, MS error = 1.01. The reliable Sex x Degree interaction, $F(2, 120) = 4.17$, $p < .02$, MS error = 1.01, was due to faster times by the normal males on the 45° and 90° turns.

Wayfinding Questionnaire

The version of this questionnaire presented to the Head Trauma group (Appendix C) was comprised of two sections. The first section asked a set of questions regarding wayfinding abilities before the accident and the second asked the same questions pertaining to time since the accident. Four items were not analyzed because the number of subjects responding to each was too small. This is because the answers to the preceding questions determined if these questions would be asked. Deleted from analyses were questions about getting lost in familiar environments with explicit directions (Question 5, Question 13) and getting lost in unfamiliar environments with explicit instructions (Question 7, Question 15).

The first set of questions given to the head injury group were

compared to the identical questions asked of normal subjects. This allowed a comparison between the estimation by head-injured subjects of their pre-injury sense-of-direction and that of non-head injured persons. Separate 2 x 2 (Group x Sex) ANOVAs were run for each question. There were no reliable group differences on any of the questions. Females (mean = 2.78) reported more difficulty identifying right from left (Question 3) than males (mean = 1.91), $F(1, 60) = 17.6$, $p < .001$, MS error = .91.

Each item in the second set of questions on post-injury ratings of the trauma group was compared to ratings by normals in separate 2 x 2 (Group x Sex) ANOVAs. As can be seen from Table 8, with the exception of direction sense at twenty years of age, group membership exerted a reliable influence on every question, smallest $F(1, 60) = 4.73$, $p < .04$, MS error = .85. Trauma subjects reported a poorer sense-of-direction (Question 2) and more right-left confusion (Question 3) than normals. Getting lost in familiar (Question 4) as well as unfamiliar (Question 6) surroundings was reported more often by trauma persons than by normal subjects. Persons who had experienced a head injury had more difficulty using street signs and landmarks (Question 8) than normal persons. Forgetting a goal or location (Question 9) was reported more often by head injured subjects than normals. As well, females (mean = 2.78) were more likely to experience right-left confusion (Question 3) than males (mean = 1.91), $F(1, 60) = 9.47$, $p < .004$, MS error = 1.29.

A further set of ANOVAs comparing pre and post-injury estimates with sex as a grouping factor, were computed on the data for the Head Trauma group. Sex differences did not occur for any of the questions. Table 8 illustrates the pre- and post-injury differences which were significant for all questions, smallest $F(1, 30) = 4.68$, $p < .04$, MS error = .97. Traumatized persons rated their wayfinding abilities as significantly reduced following injury.

Pearson correlation coefficients computed between the wayfinding questions and the Body turn and North misalignment time data and the average Proportion Correct and Segments to First Error measures did not produce any significant results.

Additional correlation coefficients were undertaken to determine if there were any relationships between performance measures and demographic variables specific to the head injured group. No patterns of significant correlations emerged among the performance measures for any of the variables which included, number of accidents, months since accident, loss of consciousness, depression status, type of injury, and headache status at time of testing.

Table 8.

Responses to Wayfinding Questionnaire: Normal Subjects
and Pre-and Post-Injury Ratings of Trauma Subjects

Questions	Normal	Trauma Pre-Injury	Trauma Post-Injury
1. Direction sense at 20	1.51	1.94	----
2. Direction sense now	1.50	1.81	2.75 ⁺⁺
3. Right-Left difficulty	1.97	1.84	2.72 ⁺⁺
4. Lost in familiar places	1.38	1.28	1.88 ⁺⁺
6. Lost in unfamiliar places	2.25	2.31	2.84 ⁺⁺
8. Difficulty with landmarks	1.38	1.50	1.97 ⁺⁺
9. Forgetting goal	1.66	1.41	2.28 ⁺⁺

* Reliably different from Normal, $p < .04$.

+ Reliably different from Trauma Pre-injury, $p < .04$.

Note: Questions 1 & 2: ratings are 1-5, very good to very poor.
 Other questions: ratings are 1-5, never to always.

Discussion

Experiment 1

On the map-following task used in this study, elderly persons made more errors and took more time to make direction decisions than did younger people. Similarly, females, especially elderly females, made more errors and took more time to make decisions than did males. For all groups, decision time was influenced by the direction and angle of each turn and by the angular disparity between the map and the room. Elderly persons, especially females, were influenced more by these factors than young people.

Elderly people were especially disadvantaged when maps became more complex due to increases in number of turns and lines on the maps, and the frequent convergence of several lines on the same location dot. This disadvantage is illustrated by the Segments to First Error results. The more complex maps 4, 5, and 6 caused elderly persons considerably more difficulty than young people, in both map orientation conditions. The Condition x Map interaction that resulted from the analysis of the Segments to First Error data was strongly influenced by the poorer performance of older people on Maps 4, 5, and 6 in the Variant condition. It is unlikely that the difficulty caused by these longer maps was due to an increasing number of more difficult turns. The misalignment with north was fairly evenly distributed across the last dots of Maps 4, 5, and 6. When the seventh and later dots of these three maps are considered, only two were at 135° of map

misalignment and none were at 180° , the two degree levels that had the most impact on performance. Although half of these last dots involved a body turn of 135° , it is unlikely that this would be a potent enough influence to cause the deficits seen. This is because the analysis of the time data indicated that angle of body turn had less influence on decision time than map misalignment. It is more likely that the increasing number of lines on the map caused difficulty for participants in remembering where they were on the route. Elderly participants frequently commented that they couldn't remember where they were and which paths had already been traversed. They often used the strategy of tracing the route with a finger to aid in keeping track of location.

Time on dots as a measure of decision-making provided the most enlightening information about age and sex differences in map-following abilities. Time on the first dot of each map involved more than making a decision about the direction from that first location. Participants spent extra time at the beginning of the route to scan it and perhaps plan out some kind of strategy for successful completion of the route. Instructions prior to beginning the task stressed that subjects were not to attempt memorization of the route. It is likely, however, that some memorizing was taking place in spite of that restriction. The longer times on the first dots for all participants in the Variant condition suggest that subjects, knowing the difficulty of trying to stay oriented when the map could not be

turned, tried to learn the route before beginning. In the Invariant condition, the task was much easier and subjects did not need to familiarize themselves with the whole route and thus time on Dot 1 probably consisted mainly of deciding the direction of the first segment.

Overall, the pattern of the Dot 1 time analysis is very consistent with all the other analyses. Young people, particularly males, took less time than older people with elderly women taking the most time. The Dot 1 time similarities across maps for the younger people indicated a consistency in strategy, regardless of condition, that was not apparent in the performance of the elderly people. It would seem that young people, who took similar amounts of Dot 1 time on each map for planning, were uninfluenced by particular features specific to each map. The lack of uniformity across maps for the Dot 1 times of the elderly persons shown in Figure 5, indicates that elderly people did not have a consistent strategy. Their times were probably influenced by attributes of each individual map although they do not seem to be correlated with specific map features such as angle of turn or complexity of the map. The exception may be the sharp time increase on Dot 1 of Map 3 shown by the elderly females. This time was probably influenced by the fact that it was a 135° right turn and Body Dot time data indicated elderly females had considerable difficulty with those turns throughout the task.

The influence of direction and angle of required turn independent

of the map misalignment was assessed in the Body Dot time analysis. Evidence in the literature (Harris & Gitterman, 1978) indicating that females have more difficulty than males when making right-left decisions, explains the higher times taken by women. This is reinforced by the stronger incidence of right-left confusion reported by women in this study (Wayfinding question 3).

The right-left differential that occurred in this study cannot be explained by any previously reported research. Part of this effect is probably due to the right 45° turns in the Variant condition on which all groups had difficulty relative to comparable left turns. As can be seen from Table 3 (pg. 37), all dots fitting the right 45° category were misaligned with North by 135° and 180° , whereas the left 45° dots were nearly all at 0° and 45° misalignment. The elderly females had particular difficulty with those turns and that influenced the strength of the right-left effect. With the exception of the elderly females, right-left differences were not apparent in the Invariant condition. This suggests that interactions between body turns and map misalignment as well as other uncontrolled influences in the stimuli were probably responsible for the effect.

The overall differences between the three degree sizes of body turn is consistent with the well known 'oblique effect' (Appelle, 1972). This effect is the apparent ease with which people make discriminations along the horizontal or vertical axes compared to obliques which "occupy both coordinates of space simultaneously"

(Rudel, 1982, pg. 129). Participants in this study took less time to make decisions about 90° turns than they did for the other two turns on the map-following task as well as in the Body condition of the verbal maze task. Also, subjects had difficulty with the oblique coordinates of the compass during the External version of the verbal maze. Similar results were reported by Loftus (1978) who demonstrated that subjects took more time to make judgements about the oblique directions within the four quadrants of the compass than other directions.

The longer times taken on 135° turns by subjects in the present study reflect data reported by Bk and Grling (1981b). Although their subjects were not engaged in a map-following task, they were required to estimate target directions following changes in body position. Estimation errors increased linearly with angle of body rotation.

In a discussion of spatial problem solving, Levine et al. (1982) pointed out that alignment of the map in the direction one is following results in fewer errors and faster goal attainment. The authors indicated that, although this alignment principle is recommended by orienteering manuals such as the Boy Scout Handbook (1965), they were unaware of any research supporting it. Similarly, in a discussion of "you-are-here-maps" frequently found in shopping malls and airports, Levine (1982) emphasized the importance of orienting such maps so that the top of the map (which is virtually

always vertical) corresponds to forward. In the present research, consistent alignment of the map with North resulted in fewer errors and shorter decision times than map misalignment, congruent with Levine's principle.

In the present study, it is in the analysis of the influence of map misalignment (North Dot time) that this effect is best understood. The results of this analysis strongly suggest that when people try to follow a map that is misaligned with the environment, successful completion of the route can only be achieved if a mental rotation of the map is effected. A study reported by Shepard and Hurwitz (1985) required subjects to make right-left judgements of turns in a randomly bending path. In this task, which was somewhat analogous to map-reading, time to make such judgements increased with the angular disparity of the line from upright. Their data, as did the data from the present study, mimicked that seen in typical mental rotation research (Cooper & Shepard, 1973a 1973b; Corballis & McLaren, 1984).

Figure 6 represents the North Dot decision time data and mirrors that found in many mental rotation studies. The curvilinear shape of the data, although not as common a result as a linear shape, is representative of the increasing time taken to mentally rotate through greater angles of disparity (Cooper and Shepard, 1973a, 1973b). These data strongly suggest that a mental rotation strategy was employed to complete the routes. However, other cognitive procedures were probably taking place as well. For instance, the equality

between the 0° and the 45° turns does not fit the usual mental rotation curve. Presumably, the interaction of other factors such as complexity and body turn, masked the influence of possible rotation. Alternatively, subjects may not have needed to employ mental rotation at 45° . The slow acceleration of the curve for both groups from 45° to 90° suggests that, if subjects were mentally rotating the map in order to achieve congruence with the environment, they were employing the strategy very effectively. The sharp increase in slope over 135° and 180° misalignments suggests that, the elderly subjects at least, were unsure of what strategy to use and how to apply it. This task differs from typical rotation studies because subjects did not have available a correctly oriented stimulus for comparison.

The decrease in slope of the 180° turns evidenced by the young males may be due to a different strategy being used by this group. Perhaps young men were more likely to recognize that, when the map was misaligned 180° , the direction of turn is opposite to the absolute right-left direction indicated by the path (Hintzman, O'Dell, & Arndt, 1981). This explanation assumes that right-left decision-making constitutes a significant portion of direction choice time. It is likely that the advantage young men had on such turns was a combination of the fact that two of the turns were simple 90° choices, with the above strategy benefiting decisions, and that the other two turns occurred near the end of their respective routes. In the latter case, the arrowhead pointing to the last dot served as a potent cue.

It would seem that young men, who consistently outperformed all others on this task, were able to take advantage of such cues and utilize the more efficient strategies.

The graph of North Dot times in combination with Body Dot times (Figure 8) illustrates the relative importance of map misalignment to decision making time. Although there is a general trend for increased times with increasing degrees of body turn, the strongest effect is obviously due to map misalignment. The unexpected drop in times for the 45° Body turn at 135° of map misalignment compared to the 0° Body turn is probably due to stimulus characteristics. Of the three dots that contributed to this category, two were extremely similar turns and were separated by only one turn on the same map (Map 5, Dots 2 and 4). Performance on the first dot may have facilitated decision time on the near identical dot that followed. The third dot in the category, Map 3 Dot 8, is the final dot for that route on which a direction decision had to be made. The ending arrowhead may have served as a strong cue for direction decision.

The age effects represented in these data have been reported by other researchers assessing mental rotation abilities (Berg et al., 1982; Cerella et al., 1981; Gaylord & Marsh, 1975). Elderly persons consistently took more time to make decisions than young people and the slope of the mental rotation function was steeper and more nonlinear for the older group.

The finding that women did more poorly on this task is congruent

with the male-female differences in mental rotation abilities reported elsewhere in the literature. The differential decline of the elderly females is more problematic. Not only did elderly women take more time to make decisions when the map was misaligned, but even when the factor of map misalignment was removed in the Invariant condition, they still required more time to make decisions than elderly males and young people.

Berg et al. (1982) investigated sex differences on a mental rotation task and reported similar extreme times for the elderly females as seen in the present data. Those researchers gave extra practice over four days on the task and noted improvements across all groups, although the Age x Sex interaction still occurred. They did note, however, that the older females showed the greatest improvement with practice. The Seattle Longitudinal Study investigated mental rotation abilities using the Thurstone Primary Mental Ability test of Spatial Orientation (Willis, 1986; Willis & Schaie, 1984). They reported that older subjects could be divided into two groups, stable persons who evidenced no significant change in performance, and decliners, whose performance deteriorated by at least one standard deviation over fourteen years. There were no differences in the proportion of males and females in these two groups, although the mean age for the decline group was significantly older than the stable group. When some of these subjects were given training, women decliners showed the greatest improvement in speed and accuracy

scores. In addition, post-test results indicated a significant reduction in sex differences among both decliners and stables.

The explanation for the differential performance of elderly females on mental rotation tasks and the mental rotation component of map-following is difficult to find. Superficially, it is easy to suggest that aging exacerbates the sex differences that have been demonstrated in numerous tests of spatial performance. If this were the case, older women shouldn't show the beneficial effects of practice and training reported in previous studies (Berg et al., 1982; Willis, 1986; Willis & Schaie, 1984). Such effects indicate that the differences are due to experience and not a differential deterioration in neurological or physiological substrates. Why should men have more experience with mentally rotating either objects or maps than women? The women in the present study frequently stated that they did not drive or, as passengers, help navigate, and claimed that difficulty with the map-following task was due to this inexperience. The majority of research investigating the effects of age on psychometric assessments of spatial ability does not reveal similar sex differences. The present results and those reported by Willis (1986) and Berg et al. (1982) may be due to sampling variability or experiential factors specific to this cohort. Young women of the 1980's are more likely to drive than older women and they have been involved in a wider range of careers including many that were traditionally restricted to men. If experience affects performance on

spatial orientation tasks, we could expect that, if the young women who participated in this study were to be tested again in thirty years, exacerbation of the female-male spatial ability differences would not occur as it did in this study.

By giving the participants of this study verbal directions for Map 6 which required no memory of location, it was intended that a comparison could be made to the map-following task which involved some reliance on short-term memory. As it turned out, subjects found the use of Body coordinates in a verbal direction following task more difficult than the Variant map following task. The use of body coordinates, if given only as right or left turns, would probably not have been inordinately difficult. The addition of degrees of turn made the Body-Verbal task too unfamiliar for most subjects. Although they were given extra practice prior to testing if wanted, most participants still had trouble with the task.

If only the External coordinate data is considered, some comparisons can be made to the map following task. North was marked on the maps and thus participants had at least one compass direction as a cue. Similarly, for both conditions, the experimenter's location represented North. In both cases, subjects did not have any specific landmarks with which to identify the other points of the compass.

In the map following task, subjects may or may not have chosen to maintain orientation in terms of compass directions. Indeed, the task could probably have been completed equally as well if a black square

marked the top of the map and one wall of the room was designated as the matching wall. Time on each dot in the Invariant-Map condition included the physical rotation of the map as well as right-left direction and degrees of required turn decisions.

In the External-Verbal condition, subjects had to keep oriented to the positions of the compass at all times. If subjects had been standing in the middle of the room and merely had to point in the directions required, they probably would have taken even less time to make decisions. However, they were to make direction decisions from several different orientations which required recurrent updating of position in relation to the compass coordinates. For decisions about North, South, East, or West, if a subject had maintained the relationship between his or her own body and these four points, the decision time would be relatively short. For the oblique coordinates, such as Southwest, the subject may have had to locate both South and West and then determine the direction between those two coordinates, thus requiring more time for those decisions.

Although the Invariant-Map and External-Verbal conditions have somewhat different processing requirements, using verbal External compass coordinates was at least as easy as being allowed to rotate the map. On the measure of successful completion (Proportion Correct), Segments to First Error, and average dot time, performance on the External-Verbal and Invariant-Map conditions was similar.

The Variant-Map condition, wherein subjects had to keep track of

location and mentally rotate the map, required more time to make decisions and resulted in fewer completed segments than the other two conditions. There were different, more demanding processing requirements specific to the Variant-Map condition. While on a dot, the subject had to verify that the present dot was indeed the correct one according to the map, remember which path had already been traversed in order to decide which must be followed next, and hold that in memory while mentally rotating the map in order to decide the correct direction for the next segment. Thus, the demands on working memory in this condition were much greater than in the other two conditions.

Answers given to the Wayfinding Questionnaire provide information about the participants' knowledge of their own wayfinding abilities. Older people rate their senses-of-direction as poorer than young people and the correlations between these ratings and the various time measures indicate that they have fairly accurate perceptions about their own abilities. These correlations between sense-of-direction and performance confirm those found by Kozlowski & Bryant (1977) and extend the relationship to include adults beyond college age and to senior citizens. In the current study, it is somewhat surprising that there were no sex differences on this question, although females did feel that at twenty years of age they had poorer direction-sense than males. Although statistical correlations did not occur between performance and some of the other wayfinding questions, the data

indicate that females are aware of their orienting difficulties.

Longer times for Body Dot decisions reflect the right-left identification difficulty reported by women. The consistent occurrence of sex differences on all measures taken in this study suggests that women find orientation tasks more difficult than men and not surprisingly, they report getting lost in unfamiliar places more often. The Age x Sex interaction that could be expected on several of the wayfinding questions based on the consistently poor performance of the elderly females in this study, did not occur. Perhaps, although women are aware of a poorer direction sense than men, older women do not recognize their deficiencies as being particularly extreme.

Experiment 2

As in Experiment 1, condition, map complexity, direction and degree of body turn, and map misalignment, influenced the performance of all subjects. Persons who had experienced a mild head injury made no more errors on the map following task than did age-matched controls. They did, however, take more time to make direction decisions, and these decisions were primarily influenced by misalignment of the map.

As in the previous experiment, the accelerating time curve accompanying greater angular disparity of the map, suggests that subjects mentally rotated the map in order to make decisions. Misalignment of the map caused head injured persons to take more time to make decisions than normals. This increase in decision time is

similar to that seen with elderly subjects and may reflect reductions in the speed of processing. Decreases in the rate of information processing for head injured persons (O'Shaughnessy et al., 1984) has been reported. Other researchers with head injured persons have noted attention deficits (Rimel, Giordani, Barth, Boll, & Jane, 1981). It may be that the head injured subjects in this study had difficulty maintaining concentration and this resulted in slower decision times. If attentional difficulties were the cause, however, one might have expected more errors, especially on the more complex maps when it was most difficult to maintain location of place.

For the trauma group, decision time increased dramatically with the more acute angles of 135° and 180° . As with elderly persons, the sharp increase at the more acute angles could indicate that trauma subjects were unsure of what strategy to employ (i.e. mental rotation) and the efficient use of that strategy. The control subjects, on the other hand, showed the same curvilinear increase in times but a flattening out of the curve at the 180° misalignment. The increased time at 180° taken by the normal females was tempered by the faster times of the normal males who seemed able to utilize the most efficient strategies for completing the task such as map cues (arrowhead on the last dot) and reversal of absolute right-left direction when the map was misaligned 180° . Segment time data followed the same patterns as the dot time data, indicating that the North Dot time effects were probably underestimated and time to make

direction choice decisions took place while the subject was walking the segment as well as while on the dot.

The influence of direction and degree of body turn independent of map misalignment is not as clear in these data as it was in Experiment 1. Analysis of Body Dot time did not reveal any reliable effects although the Body Segment analysis resulted in several reliable interactions. Since it appears that some segment time was used by participants in this study for decision-making, the latter results suggest that direction and degree of turn affected decision time, particularly for the head injured group. As well, Figure 12 indicates a greater increase in the trauma group's time for comparable degrees of misalignment at each subsequent level of body turn. One explanation may be that the head injured subjects might not have been monitoring their decisions very well and were starting off from a dot without being completely sure of the correctness of a decision. Another possibility is, that once having made a decision, they lacked confidence in that decision and continued to verify the choice while walking the segment.

These data do not indicate reliable sex differences on any of the measures taken. Contrary to data from Experiment 1 where age seemed to exacerbate the usual sex differences found on spatial tasks, head injury appeared to have eliminated those differences. It is important to note, however, that the males in the head injured group may have suffered more severe injuries than the females when length of

loss of consciousness is considered. Females averaged 2.4 minutes LOC, while males averaged 12.4 minutes. If males and females had been matched on LOC, the usual sex differential in favour of males might have resulted. In the analysis of Dot 1 times across maps shown in Figure 9, time differences between normal males and females are apparent, but do not exist between trauma males and females. The only measure on which Sex differences appeared was on decision times in the Body-Verbal condition. The fact that females took longer than males, reflects the right-left confusion difficulties reported by females in this (Wayfinding Question 3) and other research.

The responses to the Questionnaire items illustrate how salient wayfinding is to the head injured group. The comparison of the responses of the normal subjects to the pre-injury responses of the head injured group, indicates that the trauma group, before injury, rated themselves as no different from an age-matched non trauma group. The comparisons between normals and post-injury responses, and the pre-injury to post-injury comparisons indicate that head injured persons have noticed dramatic changes in their ability to navigate in their environment since being injured.

General Discussion

The results of this research indicate that older persons and young people who have suffered a minor head trauma experience difficulties in spatial orientation. Although different etiologies distinguish these groups, both are characterized by diffuse neurological changes

in the brain. The major point of similarity between the performances of elderly and head injured persons was the increased time taken on dots, presumed to be a measure of direction choice time. For both groups the patterns of decision time as influenced by body turn and map misalignment did not differ from those of the control group. However, overall times were longer. A slowed rate of information processing has been cited as a cause for cognitive deficits for both these groups (Birren, Woods, & Williams, 1980; Cerella, 1985; Gronwall & Wrightson, 1981; O'Shaunessy et al., 1984) and the longer times are consistent with this interpretation. Deficits in working memory also have been reported for elderly persons (Light & Anderson, 1985, Rule & Dobbs, 1987) and head injured subjects (Dobbs & Rule, 1987). The working memories of participants in this study were taxed heavily, particularly during the Variant form of the map-following task. Head injured persons took more time to deal with the mental manipulations required to successfully complete the routes, but did not make more errors than control subjects. Older people, on the other hand, not only took longer to make direction choices, but made more errors than young people (normal and head injured). It may well be that for older persons this slower processing makes heavy demands on short-term memory capacity such that breakdowns occur and errors result.

Deficits in information processing speeds and working memory appear to explain some of the effects for both groups. The fact that sex differences were found in these data but have not been reported in

studies of processing and working memory, implicates other influences such as spatial orientation difficulties. Spatial orientation difficulties are further implicated by the increased times taken by both elderly and head injured persons compared to normal, young people on the verbal tasks in which working memory and mental rotation demands were virtually eliminated.

Deficiencies in both intrapersonal and extrapersonal spatial mechanisms are implicated by these data for both elderly and head injured persons. Difficulties with the use of the body as a referent were apparent from the analysis of the Body Dot times for the elderly group. Although, dot times didn't indicate reliable differences between trauma and normal subjects on this variable, the segment time results suggest that trauma subjects were somewhat disadvantaged in the use of personal referents. Both groups also took longer to make decisions than the control group in the Body-Verbal condition. The analysis of the North time data indicated that orientation while using external referents was less efficient for both groups, particularly for elderly persons. Performance on the External-Verbal map indicated similar results. Interestingly, the oblique effect holds in both intra- and extrapersonal space.

There appeared to be strategy differences in the way these two groups approached the problem of solving these tasks. Time on the first dots of each map for both map-following conditions is believed to include planning about how to complete the route. Comparison of

Figure 5 (Experiment 1) and Figure 9 (Experiment 2) indicates a lack of uniformity across maps for elderly people that wasn't apparent in the performance of the head injured subjects. This suggests that normal, young people and head injured persons employed a consistent strategy when planning each route, while elderly persons were unable to rely on a strategy and may have been influenced by features specific to each map.

There was no apparent differential influence of map complexity on the performance of the trauma subjects. In contrast, elderly persons appeared to be negatively influenced by this factor as evidenced by the increase in errors made on the latter three maps.

The data from Experiment 1 followed most of the psychometric evidence for sex differences on spatial tasks and further indicated an exaggerating effect of age on this difference. Surprisingly, head injury had the effect of eliminating the usual sex difference; trauma males were affected more by the injury than females. It would seem that if one is female and old or head injured and a young male, one is more likely to have spatial orientation problems.

Diffuse brain damage of the type found after a minor head injury is likely to influence an individual's ability to orient in space. In any orientation task outside the laboratory, competing situational demands and need for speed will undoubtedly result in errors as well as longer times to make orientation judgements. Cerebral changes that occur as a result of normal aging also affect spatial orientation. For

elderly persons, not only do slower information processing and decreases in working memory capacity affect performance, but susceptibility to task complexity and poor problem-solving strategies also compromise success. For elderly persons these changes are gradual and most have adapted and learned to make compromises and therefore do not find way-finding difficulties to be a major problem in their lives. For a young person who receives what seems to be a relatively mild injury, performance on way-finding tasks may not be as poor as for an elderly person, but is much more salient and interferes more with daily living because the onset is so sudden and unexpected.

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Appendix A

ALCOHOL CONSUMPTION QUESTION AND MEAN RATINGS FOR EACH GROUP

If you drink alcohol, how much of the following kinds of alcohol do you drink per week?

	Young Control	Elderly	Head Injured
Oz. of wine	4.1 (4.98)	5.6 (9.9)	2.2 (4.7)
Bottles of beer	1.7 (4.6)	.1 (.25)	2.0 (5.5)
Oz. hard liquor	1.8 (2.5)	4.0 (9.3)	2.1 (9.0)

Note: Standard deviations are in brackets.

Appendix B

WAYFINDING AND DIRECTION-SENSE QUESTIONNAIRE (Normal)

1. How good was your sense-of-direction when you were twenty years old?
1 very good; 2 good; 3 average; 4 poor; 5 very poor
2. How good is your sense of direction now?
1 very good; 2 good; 3 average; 4 poor; 5 very poor
3. As an adult, have you noticed difficulty when you have to quickly identify right versus left?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
4. Have you ever been lost within familiar surroundings such as your place of work, home, or favorite shopping centre?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

5. If given explicit directions, do you ever get lost in familiar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
6. Have you ever been lost within unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

7. If given explicit directions, do you ever get lost in unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
8. Do you ever have difficulty using street signs and familiar landmarks as aids to help you find your way?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
9. Do you ever start out with the intention of reaching a particular goal or location, only to forget the purpose or goal before getting there?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

Appendix C

WAYFINDING AND DIRECTION-SENSE QUESTIONNAIRE (Head Trauma)

The first set of questions relates to your wayfinding abilities before your injury. Please try to recall how as an adult, you handled these situations previous to your injury.

1. How good was your sense-of-direction when you were twenty years old?
1 very good; 2 good; 3 average; 4 poor; 5 very poor
2. How good was your sense of direction just before your accident?
1 very good; 2 good; 3 average; 4 poor; 5 very poor
3. Did you notice difficulty when you had to quickly identify right versus left?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
4. Were you ever lost within familiar surroundings such as your place of work, home, or favorite shopping centre?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

5. If given explicit directions did you ever get lost in familiar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
6. Were you ever lost within unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

7. If given explicit directions, did you ever get lost in unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
8. Did you ever have difficulty using street signs and familiar landmarks to help you find your way?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
9. Did you ever start out with the intention of reaching a particular goal or location, only to forget the purpose or goal before getting there?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

The following questions relate to your wayfinding abilities since your injury.

10. How good is your sense of direction now?
1 very good; 2 good; 3 average; 4 poor; 5 very poor
11. Have you noticed difficulty when you have to quickly identify right versus left?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
12. Have you ever been lost within familiar surroundings such as your place of work, home, or favorite shopping centre?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

13. If given explicit directions, do you ever get lost in familiar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
14. Have you ever been lost within unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

If the answer to the above question is 3, 4, or 5, then ask:

15. If given explicit directions, do you ever get lost in unfamiliar surroundings?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
16. Do you ever have difficulty using street signs and familiar landmarks as aids to help you find your way?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always
17. Do you ever start out with the intention of reaching a particular goal or location, only to forget the purpose or goal before getting there?
1 never; 2 rarely; 3 sometimes; 4 often; 5 always

Appendix D

LOCOMOTOR MAZE - GENERAL INSTRUCTIONS

"The tasks I am going to be having you do over the next two sessions will tell me something about your sense of direction. You will be asked to use the dots on the floor as landmarks in a number of route-following tasks. These are not speed tests although I will be timing your performance. I am much more interested in your accuracy at doing the tasks and want you to proceed at a pace that is comfortable for you. As you can see, I have a video camera set up in the room and will be videotaping you while you do these tasks. My purpose for taping the procedures is because I have to try to do several things at once while you are going through these tasks and I want to be able to recheck later in case I made any mistakes.

LOCOMOTOR MAZE - VARIANT CONDITION INSTRUCTIONS

"I am going to give you a series of maps with dots marked on them that correspond to the red discs on the floor of this room. North is marked on the maps - I will be standing at the North wall of this room. For each map, I will tell you on which dot to start and you are to face North on that dot before beginning the map. You will please walk along the route beginning with the circled dot and ending with the dot marked with an arrowhead. Please hold the map in front of you with its northernmost edge farthest away, and keep it in that relation to you, even though it won't always be in the proper orientation to the room. Walk directly forward - do not walk backward or sideways. Previous research has indicated that if, at the beginning of a route, people attempt to memorize the route, they often forget part of the way through and become confused. Please do not try to memorize the route. Beginning with the circled dot, make your decision for the first turn only and proceed to the next dot. At that point, do not turn until you have decided to which point you are going next. I will give you three practice routes to try out first."

Hand the practice maps to the participant, one at a time, being sure that each map is held in the correct orientation. Assist the participant whenever necessary. Once the participant has completed the practice routes and you are certain the instructions are understood, proceed with the actual test maps.

"Now I will give you six more maps, but I will not be helping you in any way while you follow these routes. I am giving you

all six maps at once. When you have completed the first map, please do not turn to the next map until I tell you to do so and have lead you to the appropriate first dot. This is not a speed test, so please proceed at your own pace. Here are the first maps. Please follow the path outlined on the first map, beginning with the circled dot."

Appendix E

LOCOMOTOR MAZE - INVARIANT CONDITION INSTRUCTIONS

"I am going to give you a series of maps with dots marked on them that correspond to the red discs on the floor of this room. North is marked on the maps - I will be standing at the North wall of this room. For each map, I will tell you on which dot to start and you are to face North on that dot before beginning the map. You will please walk along the route beginning with the circled dot and ending with the dot marked with an arrowhead. Please hold the map in front of you with its northernmost edge farthest away, and keep it in that relationship to the room as you complete the route. In other words, I want you to rotate the map as you rotate your body while moving along the path. Walk directly forward - do not walk backward or sideways. Previous research has indicated that if, at the beginning of a route, people attempt to memorize the route, they often forget part of the way through and become confused. Please do not try to memorize the route. Beginning with the circled dot, make your decision for the first turn only and proceed to the next dot. At that point, do not turn until you have decided to which point you are going next. I will give you three practice routes to try out first."

Hand the practice maps to the participant, one at a time, being sure that each map is held in the correct orientation. Assist the participant whenever necessary. Once the participant has completed the practice routes and you are certain the instructions are understood, proceed with the actual test maps.

"Now I will give you six more maps, but I will not be helping you in any way while you follow these routes. I am giving you all six maps at once. When you have completed the first map, please do not turn to the next map until I tell you to do so and have lead you to the appropriate first dot. This is not a speed test, so please proceed at your own pace. Here are the first maps. Please follow the path outlined on the first map, beginning with the circled dot."

Appendix F

MAZE INSTRUCTIONS: EXTERNAL VERBAL

"I am going to give you verbal instructions to follow a specific path around the room using the red dots on the floor as landmarks. I want you to stand on the first dot that I specify and then to walk one dot in the direction I tell you. Please stop at each dot and wait until I have completed the instructions before turning or moving on to the next location. You will be moving only one dot at a time so the instruction given each time will be the direction you are supposed to take. I will be standing at the North end of the room. All the turns you will be asked to make will be directions of the compass: north, south, east, west, north-west, south-east etc." Be sure the participant is able to indicate by pointing all directions.

"Are there any questions? Then let's begin with a practice route." Lead the participant to the correct starting dot (centre front dot), facing the experimenter (north).

Practice Route:

1. Southwest 2. Southeast 3. North
4. Northeast 5. South 6. Southwest

The participant should end on the centre rear dot if route was done correctly.

Test Route:

1. East 2. Southwest 3. East 4. North 5. East 6. Southwest
7. East 8. North 9. Northwest 10. West 11. Southeast

Appendix G

MAZE INSTRUCTIONS: BODY VERBAL

"I am going to give you verbal instructions to follow a specific path around the room using the red dots on the floor as landmarks. I want you to stand on the first dot that I specify and then to walk one dot in the direction I tell you. Please stop at each dot and wait until I have completed the instructions before turning or moving on to the next location. You will be moving only one dot at a time so the instruction given each time will be the direction you are supposed to take."

"You will be asked to make 45°, 90°, and 135° turns to the right or left." Demonstrate these turns to the participant and be sure that he/she understands and is able to make the turns as directed.

"Are there any questions? Then let's begin with a practice route."

Lead the participant to the correct starting dot (centre front dot), facing the experimenter (north).

Practice Route:

1. 135° L 2. 90° L 3. 135° L
4. 45° R 5. 135° R 6. 45° R

The participant should end on the centre rear dot if done correctly.

Test Route:

1. 90° R 2. 135° R 3. 135° L 4. 90° R 5. 90° R 6. 135° R
7. 135° R 8. 90° L 9. 45° L 10. 45° L 11. 135° L